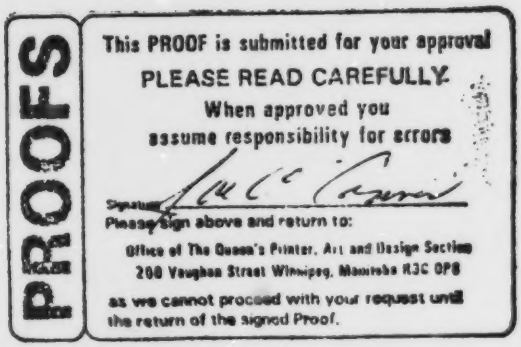
Gaboury, M.N., and J.W. Patalas. 1982


PROOFS
This PROOF is submitted for your approval
PLEASE READ CAREFULLY
When approved you
assume responsibility for errors
Signature
Please sign above and return to:
Office of The Queen's Printer, Art and Design Section
200 Vaughan Street Winnipeg, Manitoba R3C 0P8
as we cannot proceed with your request until
the return of the signed Proof.

The Fisheries of Cross, Pipestone and Walker lakes, and effects of hydroelectric development.

MANITOBA
DEPARTMENT OF NATURAL RESOURCES
Fisheries Branch
Biological Services

MS Report No. 82-14, 198pp.

90-05898/

Gaboury, M. N., and J. W. Patalas. 1982. The fisheries of Cross, Pipestone and Walker lakes, and effects of hydroelectric development. Man. Dept. Nat. Res. MS Rep. No. 82-14

ABSTRACT

The fish stocks of Cross, Pipestone, and Walker lakes were assessed, and the impacts of the current water level regime, as regulated by the Jenpeg hydroelectric impoundment, were determined. Differences in age distributions, and growth rates indicated that the east and west basins of Cross Lake were comprised of discrete populations of whitefish *(Coregonus clupeaformis)*, walleye *(Stizostedion vitreum vitreum)*, pike*(Esox lucius)* and cisco *(Coregonus artedii)*. Under regulation, water level drawdown has contributed to a decrease in the absolute abundances of Cross and Pipestone lakes fish by causing a winterkill in March, 1981, and by detrimentally affecting coregonid hatching success and recruitment, apparently through a de-watering of their spawning areas and desiccation of the eggs. Low spring water levels have prevented walleye and pike access to their spawning areas, while low summer levels have reduced the available habitat for plankton, benthos and fish. Walker Lake fish stocks do not appear to be impacted by Jenpeg regulation. Changes to the commercial quotas on Cross and Pipestone lakes are recommended. A minumum Cross Lake stage of 206.5 m is recommended if the outlet control structure is constructed, and an interim water level regulation scheme is proposed.

TABLE OF CONTENTS

	Page
ABSTRACT	i
ACKNOWLEDGMENTS	106
LIST OF TABLES	v
LIST OF FIGURES	viii
LIST OF APPENDICES	xi
INTRODUCTION	1
MATERIALS AND METHODS	3
Lake Morphometry	3
Physical and Chemical Water Quality	3
Plankton	11
Benthos	11
Experimental Fishing	12
Calculations	13
RESULTS	15
Lake Morphometry	15
Physical and Chemical Water Quality	15
Plankton	20
Benthos	20
Fisheries	22
.Species Composition and Catch per Unit of Effort	22

Page

Whitefish 27

Age Structure 27

Mortality. 30

Growth 33

Maturity 33

Diet 38

Walleye 38

Age Structure 38

Mortality 42

Growth 42

Maturity 48

Diet 48

Pike. 52

Age Structure 52

Mortality 52

Growth 57

Maturity 57

Diet 62

Cisco 62

Age Structure 62

Mortality 62

Growth 67

Maturity 73

Diet 73

Page

Sauger 73

Winterkill 73

Spawning Habitat Observations 75

Domestic Fishing Census 76

DISCUSSION. 80

Limnology 80

Fisheries 81

Effects of Drawdown on Fish Reproduction and Natural Mortality 87

Commercial Quotas 92

Proposed Water Level Regime 93

SUMMARY AND CONCLUSIONS 98

RECOMMENDATIONS 100

LITERATURE CITED 102

APPENDICES. 107

LIST OF TABLES

Table		Page
1.	Morphometry of Walker Lake	16
2.	Summary of water condition characteristics and plankton biomass for Cross, Pipestone and Walker lakes, 1981.	17
3.	Water chemistry of Cross, Pipestone and Walker lakes presented as summer means (June to Sept. 1981) of data in Appendices A13 to A18	19
4.	Mean density (number m^{-2}) of benthos in Cross and Pipestone lakes, based on data in Appendices A 19 to A22	21
5.	List of fish species gillnetted in Cross, Pipestone and Walker lakes, and their percent frequency of occurrence within each basin in 1981	23
6.	Growth parameters and mean weighted age of onset of sexual maturity for whitefish, 1981*.	29
7.	Whitefish mortality and survival rates estimated by Robson-Chapman and regression methods	31
8.	Covariance analyses of mortality and growth curves of whitefish (sexes combined), 1981	32
9.	Length-weight regressions for whitefish, 1981 . .	34
10.	Coefficients used in von Bertalanffy model of whitefish growth, 1981	37

Table Page

11. Whitefish stomach contents, 1981. 39
12. Growth parameters for walleye, 1981* 41
13. Walleye mortality and survival rates estimated by Robson-Chapman and regression methods 43
14. Covariance analyses of mortality and growth curves of walleye (sexes combined), 1981 44
15. Length-weight regression for walleye, 1981 45
16. Coefficients used in von Bertalanffy model of walleye growth, 1981. 49
17. Maturity rate equations and mean weighted age of onset of sexual maturity in walleye, 1981 50
18. Walleye stomach contents, 1981 51
19. Growth parameters and mean weighted age of onset of sexual maturity for pike, 1981 54
20. Pike mortality and survival rates estimated by Robson-Chapman and regression methods 55
21. Covariance analyses of mortality and growth curves of pike (sexes combined), 1981 56
22. Length-weight regressions for pike, 1981 58
23. Coefficients used in von Bertalanffy model of pike growth, 1981 61
24. Pike stomach contents, 1981 63
25. Growth parameters and mean weighted age of onset of sexual maturity for cisco, 1981* 65
26. Cisco mortality and survival rates estimated by Robson-Chapman and regression methods 66

Table Page

27. Covariance analyses of mortality and growth curves for cisco (sexes combined), 1981 68
28. Length-weight regression for cisco, 1981 69
29. Coefficients used in von Bertalanffy model for cisco growth, 1981 72
30. Cisco stomach contents, 1981 74
31. Fish harvest by domestic fishermen in Cross Lake between August 4, 1980 and August 2, 1981 77
32. Summary of von Bertalanffy growth parameters, mean ages of maturity and annual survival rates of Cross Lake fish (sexes combined) in 1980 and 1981 . . . 82
33. Fishing effort and catches/standard gang/16 h of whitefish, walleye and pike 84
34. Percent frequency of occurrence of mean monthly Cross Lake stages prior to regulation, 1918 - 1973. 96

LIST OF FIGURES

Figure		Page
1.	Map of Cross, Pipestone and Walker lakes	4
2.	Limnological stations (circles) and netting locations (bars) in the Sagatawak and Jenpeg basins of west Cross Lake, 1981	5
3.	Limnological station (circle) and netting locations (bars) in the Whiskey Jack basin of west Cross Lake, 1981	6
4.	Limnological stations (circles) and netting locations (bars) in the middle basin of west Cross Lake, 1981.	7
5.	Limnological stations (circles) and netting locations (bars) in the east basin of Cross Lake, 1981	8
6.	Limnological station (circle) and netting locations (bars) in Pipestone Lake, 1981	9
7.	Limnological station (circle) and netting locations (bars) in Walker Lake, 1981.	10
8.	Catch per unit of effort for fish captured in Cross, Pipestone and Walker lakes in 1981	24
9.	Age-frequencies of whitefish, 1981	28
10.	Von Bertalanffy growth curves for whitefish from the west and east basins of Cross Lake, 1981	35
11.	Von Bertalanffy growth curves for whitefish from Walker Lake, 1981	36
12.	Age-frequencies of walleyes, 1981	40

Figure Page

13. Von Bertalanffy growth curves for walleye from the west and east basins of Cross Lake, 1981 . . . 46

14. Von Bertalanffy growth curves for walleye from Pipestone and Walker lakes, 1981 47

15. Age-frequencies of pike, 1981. 53

16. Von Bertalanffy growth curves for pike from the west and east basin of Cross Lake, 1981 59

17. Von Bertalanffy growth curves for pike from Pipestone and Walker lakes, 1981 60

18. Age-frequencies of cisco, 1981 64

19. Von Bertalanffy growth curves for cisco from the Whiskey Jack and middle basins of Cross Lake, 1981 . 70

20. Von Bertalanffy growth curves for cisco from east Cross and Walker lakes, 1981 71

21. Temporal changes in fishing effort and in catch per unit effort for fish caught in 4.25 inch nets by the domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 30, 1981. 78

22. Temporal changes in fishing effort and in catch per unit effort for fish caught in 5.25 inch nets by the domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 30, 1981 79

Figure Page

23. Comparison of catch per unit of effort and relative abundance (in % above bars) for fish captured in Cross and Pipestone lakes in 1980 and 1981 85

24. Catch per unit effort for whitefish caught in 5.25 inch nets in 1977, 1980 and 1981. 86

25. Comparison of the average monthly water levels on Cross Lake under unregulated conditions (1928 - 1966) (- - -) and the levels recorded under regulation (1977 - 1981). 88

26. Relationship between winter and spring drawdown in Cross Lake and whitefish and cisco year class success, 1971 - 1981 89

27. Comparison of minimum water levels on Cross Lake between October 28 and May 31 (+), and winter/spring drawdown (bars) 95

LIST OF APPENDICES

Appendix		Page
A1.	Water condition characteristics and plankton biomass for station 1 in Cross Lake, 1981 . . .	107
A2.	Water condition characteristics and plankton biomass for station 2 in Cross Lake, 1981 . . .	108
A3.	Water condition characteristics and plankton biomass for station 3 in Cross Lake, 1981 . . .	109
A4.	Water condition characteristics and plankton biomass for station 4 in Cross Lake, 1981 . . .	110
A5.	Water condition characteristics and plankton biomass for station 5 in Cross Lake, 1981 . . .	111
A6.	Water condition characteristics and plankton biomass for station 6 in Cross Lake, 1981 . . .	112
A7.	Water condition characteristics and plankton biomass for station 7 in Cross Lake, 1981 . . .	113
A8.	Water condition characteristics and plankton biomass for station 9 in Cross Lake, 1981 . . .	114
A9.	Water condition characteristics and plankton biomass for station 10 in Cross Lake, 1981 . .	115
A10.	Water condition characteristics and plankton biomass for station 11 in Pipestone Lake, 1981.	116
A11.	Water condition characteristics and plankton biomass for station 12 in Walker Lake, 1981 . .	117
A12.	Maximum daily bottom water temperatures in the west and east basins of Cross Lake.	118

Appendix Page

A13. Water chemistry data for station 2, 1981 119

A14. Water chemistry data for station 4, 1981 120

A15. Water chemistry data for station 7, 1981 121

A16. Water chemistry data for station 10, 1981 122

A17. Water chemistry data for station 11, 1981 123

A18. Water chemistry data for station 12, 1981 124

A19. Number of benthic organisms per Ekman dredge ($523\ cm^2$) in station 1, 2 and 3. 125

A20. Number of benthic organisms per Ekman dredge ($523\ cm^2$) in station 4, 5 and 6. 126

A21. Number of benthic organisms per Ekman dredge ($523\ cm^2$) in station 7, 9 and 10 127

A22. Number of benthic organisms per Ekman dredge ($523\ cm^2$) in station 11 and 12 128

B1. Summary of commercial fish production from Walker Lake, 1942 - 1979 (based on Manitoba Govt. records) 129

B2. Catch summaries for experimental fishing sets in Walker Lake, 1981. 130

B3. Catch summaries for experimental fishing sets in the west basin of Cross Lake, 1981 131

B4. Catch summaries for experimental fishing sets in the east basin of Cross Lake, 1981 132

B5. Catch summaries for experimental fishing sets in Pipestone Lake, 1981 133

Appendix Page

B6. Mesh size effects on whitefish catches in the west basin of Cross Lake, 1981 134

B7. Mesh size effects on whitefish catches in the east basin of Cross Lake, 1981 135

B8. Mesh size effects on whitefish catches in Pipestone Lake, 1981 136

B9. Mesh size effects on whitefish catches in Walker Lake , 1981. 137

B10. Mesh size effects on walleye catches in the west basin of Cross Lake, 1981 138

B11. Mesh size effects on walleye catches in the east basin of Cross Lake, 1981 139

B12. Mesh size effects on walleye catches in Pipestone Lake, 1981 140

B13. Mesh size effects on walleye catches in Walker Lake, 1981 141

B14. Mesh size effects on pike catches in the west basin of Cross Lake, 1981 142

B15. Mesh size effects on pike catches in the east basin of Cross Lake, 1981 143

B16. Mesh size effects on pike catches in Pipestone Lake, 1981 144

B17. Mesh size effects on pike catches in Walker Lake, 1981 145

Appendix | Page

B18. Mesh size effects on cisco catches in the Whiskey Jack basin of Cross Lake, 1981 146

B19. Mesh size effects on cisco catches in the middle basin of Cross Lake, 1981 147

B20. Mesh size effects on cisco catches in the east basin of Cross Lake, 1981 148

B21. Mesh size effects on cisco catches in Pipestone Lake, 1981 149

B22. Mesh size effects on cisco catches in Walker Lake, 1981 150

B23. Age-specific mean lengths, weights and condition factors for whitefish from the west basin of Cross Lake, 1981 151

B24. Age-specific mean lengths,weights and condition factors for whitefish from the east basin of Cross Lake, 1981 152

B25. Age-specific mean lengths, weights and condition factors for whitefish from Pipestone Lake, 1981 153

B26. Age-specific mean lengths, weights and condition factors for whitefish caught in experimental sets in Walker Lake, 1981 154

B27. Age-specific mean lengths, weights and condition factors for whitefish caught in commercial nets (4.25 inch mesh) in Walker Lake, 1981 155

Appendix Page

B28. Walford plots for whitefish from the west and east basins of Cross Lake, 1981 156

B29. Brody plots for whitefish from the west and east basins of Cross Lake, 1981 157

B30. Walford and Brody plots for whitefish from Walker Lake, 1981 158

B31. Maturity schedules for whitefish, 1981 159

B32. Age-specific mean lengths, weights and condition factors for walleye from the west basin of Cross Lake, 1981 160

B33. Age-specific mean lengths, weights and condition factors for walleye from the east basin of Cross Lake, 1981 161

B34. Age-specific mean lengths, weights and condition factors for walleye from Pipestone Lake, 1981 . 162

B35. Age-specific mean lengths, weights and condition factors for walleye caught in experimental sets in Walker Lake, 1981 163

B36. Age-specific mean lengths, weights and condition factors for walleye caught in commercial nets (4.25 inch mesh) in Walker Lake, 1981 164

Appendix Page

B37. Walford plots for walleye from the west and east basins of Cross Lake, 1981 165

B38. Walford plots for walleye from Pipestone and Walker lakes, 1981 166

B39. Brody plots for walleye from the west and east basins of Cross Lake, 1981 167

B40. Brody plots for walleye from Pipestone and Walker lakes, 1981. 168

B41. Maturity schedules for walleye, 1981 169

B42. Age-specific mean lengths, weights and condition factors for pike from the west basin of Cross Lake, 1981 170

B43. Age-specific mean lengths, weights and condition factors for pike from the east basin of Cross Lake, 1981 171

B44. Age-specific mean lengths, weights and condition factors for pike from Pipestone Lake, 1981 . . . 172

B45. Age-specific mean lengths, weights and condition factors for pike caught in experimental sets in Walker Lake, 1981 173

B46. Age-specific mean lengths, weights and condition factors for pike caught in commercial nets (4.25 inch mesh) in Walker Lake, 1981 174

Appendix Page

B47. Walford plots for pike from the west and east basins of Cross Lake, 1981 175

B48. Walford plots for pike from Pipestone and Walker lakes, 1981. 176

B49. Brody plots for pike from the west and east basins of Cross Lake, 1981 177

B50. Brody plots for pike from Pipestone and Walker lakes, 1981. 178

B51. Maturity schedules for pike, 1981 179

B52. Age-specific mean lengths, weights and condition factors for cisco from the Whiskey Jack basin of Cross Lake, 1981 180

B53. Age-specific mean lengths, weights and condition factors for cisco from the middle basin of Cross Lake, 1981 181

B54. Age-specific mean lengths, weights and condition factors for cisco from the east basin of Cross Lake, 1981 182

B55. Age-specific mean lengths, weights and condition factors for cisco from Pipestone Lake, 1981 . 183

B56. Age-specific mean lengths, weights and condition factors for cisco from Walker Lake, 1981 . . . 184

B57. Walford plots for cisco from the Whiskey Jack and middle basins of Cross Lake, 1981 185

Appendix Page

B58. Walford plots for cisco from east Cross and Walker lakes, 1981 186

B59. Brody plots for cisco from the Whiskey Jack and middle basins of Cross Lake, 1981 187

B60. Brody plots for cisco from east Cross and Walker lakes, 1981 188

B61. Maturity schedules for cisco, 1981 189

B62. Age-specific mean lengths, weights and condition factors for sauger from the west basin of Cross Lake, 1981 190

B63. Age-specific mean lengths, weights and condition factors for sauger from Pipestone Lake, 1981 . . . 191

B64. Age-specific mean lengths, weights and condition factors for sauger from Walker Lake, 1981 192

B65. Water level drawdown between fall and spring in Cross Lake, 1918 - 1973, ... 193

C1. Number of domestic fishermen using 4.25 and/or 5.25 inch nets between August 4, 1980 and August 2, 1981 194

C2. Total catches in 4.25 inch mesh by each domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 2, 1981 195

Appendix Page

C3. Total catches in 5.25 inch mesh by each domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 2, 1981 196

C4. Number of fish caught in 4.25 inch mesh by the domestic fishermen in Cross Lake for each biweekly period between Aug. 4, 1980 and Aug. 30, 1981 . 197

C5. Number of fish caught in 5.25 inch mesh by the domestic fishermen in Cross Lake for each biweekly period between Aug. 4, 1980 and Aug. 30, 1981 . 198

INTRODUCTION

This report culminates a two year study initiated at the request of Manitoba Hydro in 1980. The main objectives were to assess the fish stocks in Cross and Pipestone lakes, and determine the impact of the current water level regime on the fisheries resource. The seasonal pattern of water level fluctuations in Cross and Pipestone lakes has been reversed by the operation of the Jenpeg hydro-electric development. Since regulation commenced in 1974, average summer water levels have been lower than without regulation, while average winter levels have been higher.

Manitoba Hydro also requested that a fisheries survey be conducted on Walker Lake (54°42'N lat., 96°57'W long.) in 1981 to determine if the fisheries resources have been adversely affected by Jenpeg regulation. Previous investigations on Walker Lake were limited to a brief survey on limnology-fisheries in 1963 (Anthony 1963 - data unpubl.), sampling for *Triaenophorus* infestation in whitefish in 1963 (Sunde 1964) and commercial fish sampling (D. Cook pers. comm.). Walker Lake has been commercially fished since 1942, and has a present quota of 38,555 kg (85,000 lb) of whitefish *(Coregonus clupeaformis)* and walleye *(Stizostedion vitreum vitreum)* (Appendix B1). Mesh sizes are restricted to a minimum of 10.8 cm.

The 1980 study showed that the average unregulated volumes of Cross and Pipestone lakes were reduced by 53% under regulation (Gaboury and Patalas 1981). Comparisons of growth analyses and age distributions indicated that west Cross, east Cross, and Pipestone lakes were comprised of discrete populations of whitefish, walleye

and pike *(Esox lucius)*. It was evident that reported catch declines in Cross Lake were not due to over-exploitation. Catches per unit of effort of whitefish, walleye and pike were, on average, highest in east Cross Lake and lowest in Pipestone Lake. It was hypothesized that drawdown prior to ice break-up was affecting whitefish and cisco *(Coregonus artedii)* hatching success and recruitment, through a de-watering of their spawning areas and desiccation of the eggs.

The objectives of the 1981 study were:

1. to determine the morphometry of Walker Lake,
2. to assess the fisheries - limnology of Cross, Pipestone and Walker lakes,
3. to determine the annual harvest by domestic fishermen,
4. to recommend commercial fish quotas for Cross and Pipestone lakes under the current water level regime, and
5. to recommend measures to mitigate the impacts of the current water level regime on fisheries.

MATERIALS AND METHODS

Lake Morphometry

Walker Lake was depth sounded in June, 1981 with a Furuno FG 200 MK 3 echo sounder. Transects and depth contours were drawn on a 1: 20,000 scale photobase map mosaic. The bathymetric map was used to determine lake area, volume, and mean depth according to procedures described by Hutchinson (1957).

Physical and Chemical Water Quality

Water samples (3.5 liters) were collected monthly from stations 2, 4, 7, 10, 11 and 12 (Figs. 1 - 7). Chemical analyses were performed within 48 h by the Technical Services Laboratory, Manitoba Department of Consumer and Corporate Affairs and Environment.

Water condition parameters were measured biweekly at stations 2, 4, 7, 10 and 11, and monthly from station 1, 3, 5, 6, 9 and 12. Due to the similarity in limnological characteristics between stations 8 and 9, station 8 was not sampled in 1981. Measurements included water temperature, dissolved oxygen and conductivity profiles, and transparency determinations. Temperature, oxygen and conductivity were determined with YSI electronic instruments, and transparency was estimated by a Secchi disc (20 cm diameter). In addition, summer bottom water temperatures were recorded continuously in west and east Cross Lake by two Ryan thermographs. The thermographs were

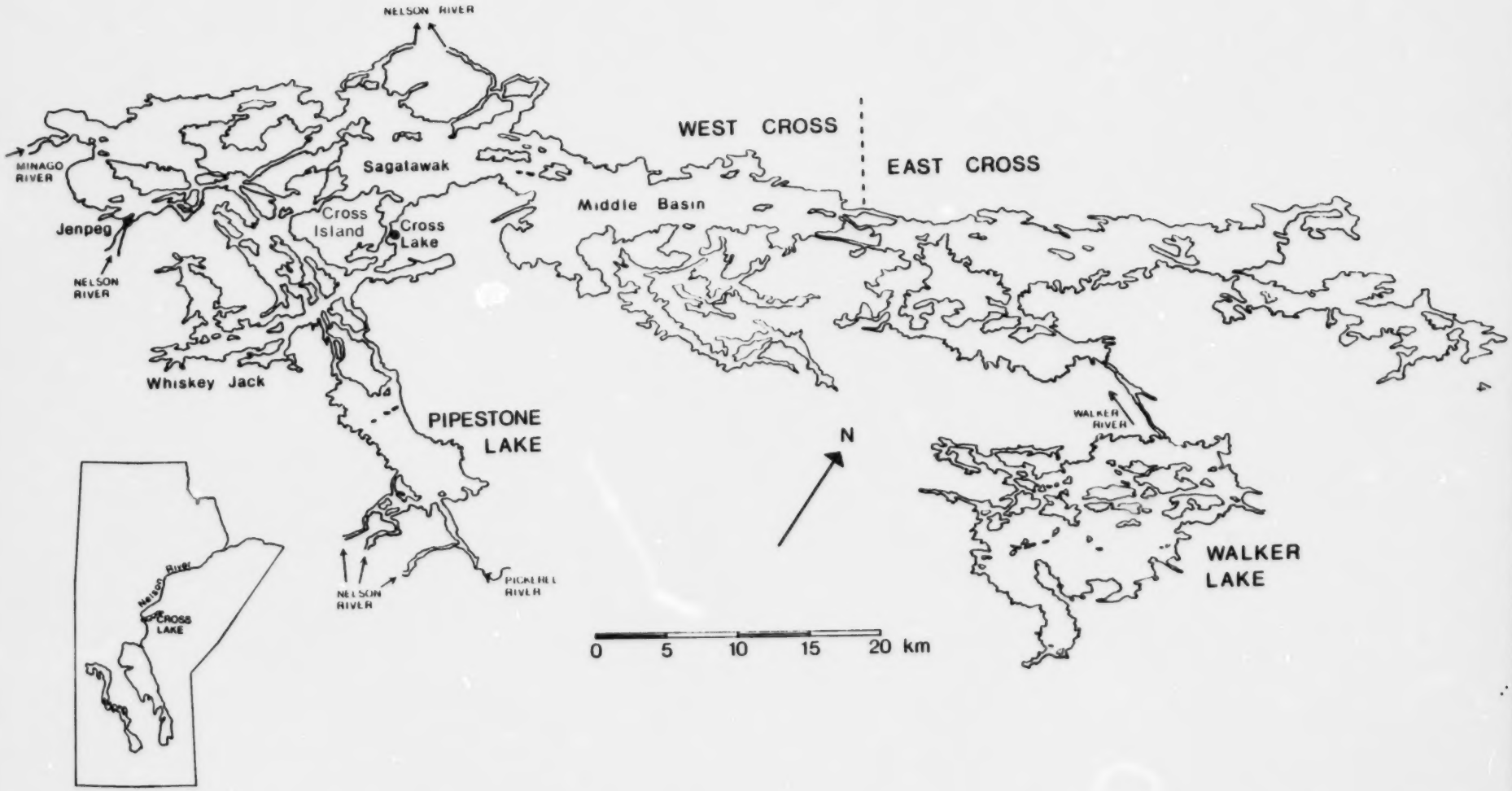


Fig. 1. Map of Cross, Pipestone and Walker lakes.

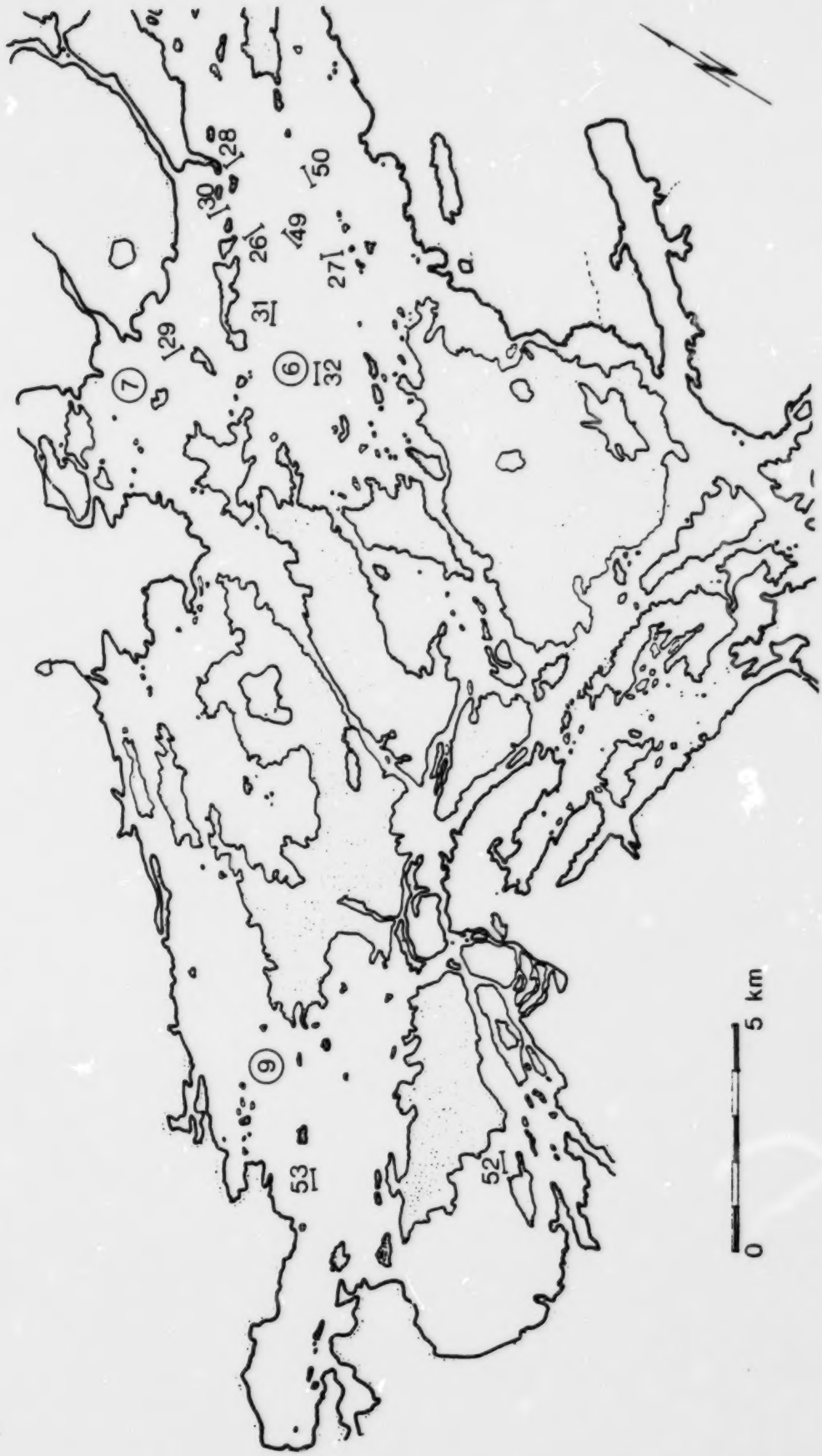


Fig. 2 . Limnological stations (circles) and netting locations (bars) in the Sagatawak and Jenpeg basins of west Cross Lake, 1981.

Fig. 3 . Limnological station (circle) and netting locations (bars) in the Whiskey Jack basin of west Cross Lake, 1981.

Fig. 4 . Limnological stations (circles) and netting locations (bars) in the middle basin of west Cross Lake, 1981.

Fig. 5 . Limnological stations (circles) and netting locations (bars) in the east basin of Cross Lake, 1981.

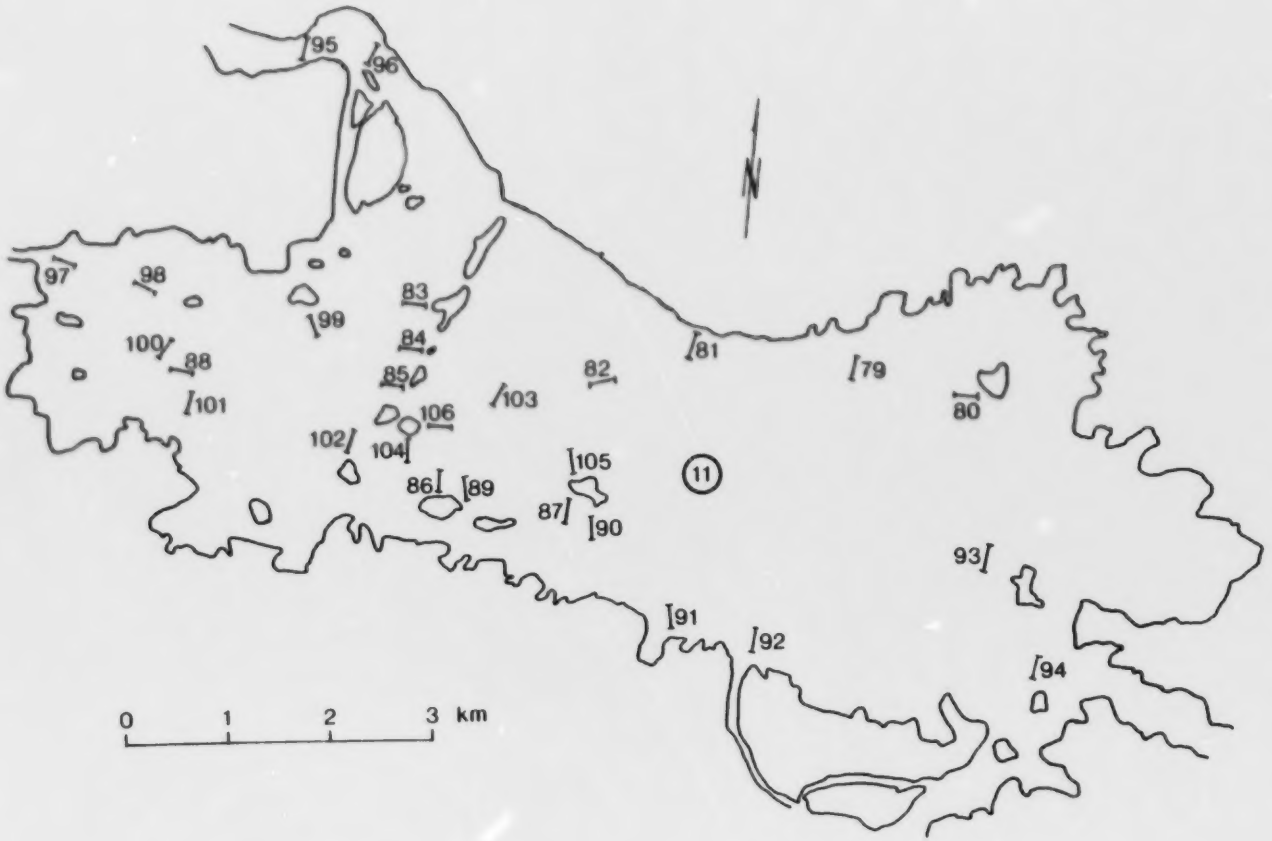


Fig. 6 . Limnological station (circle) and netting locations (bars) in Pipestone Lake, 1981.

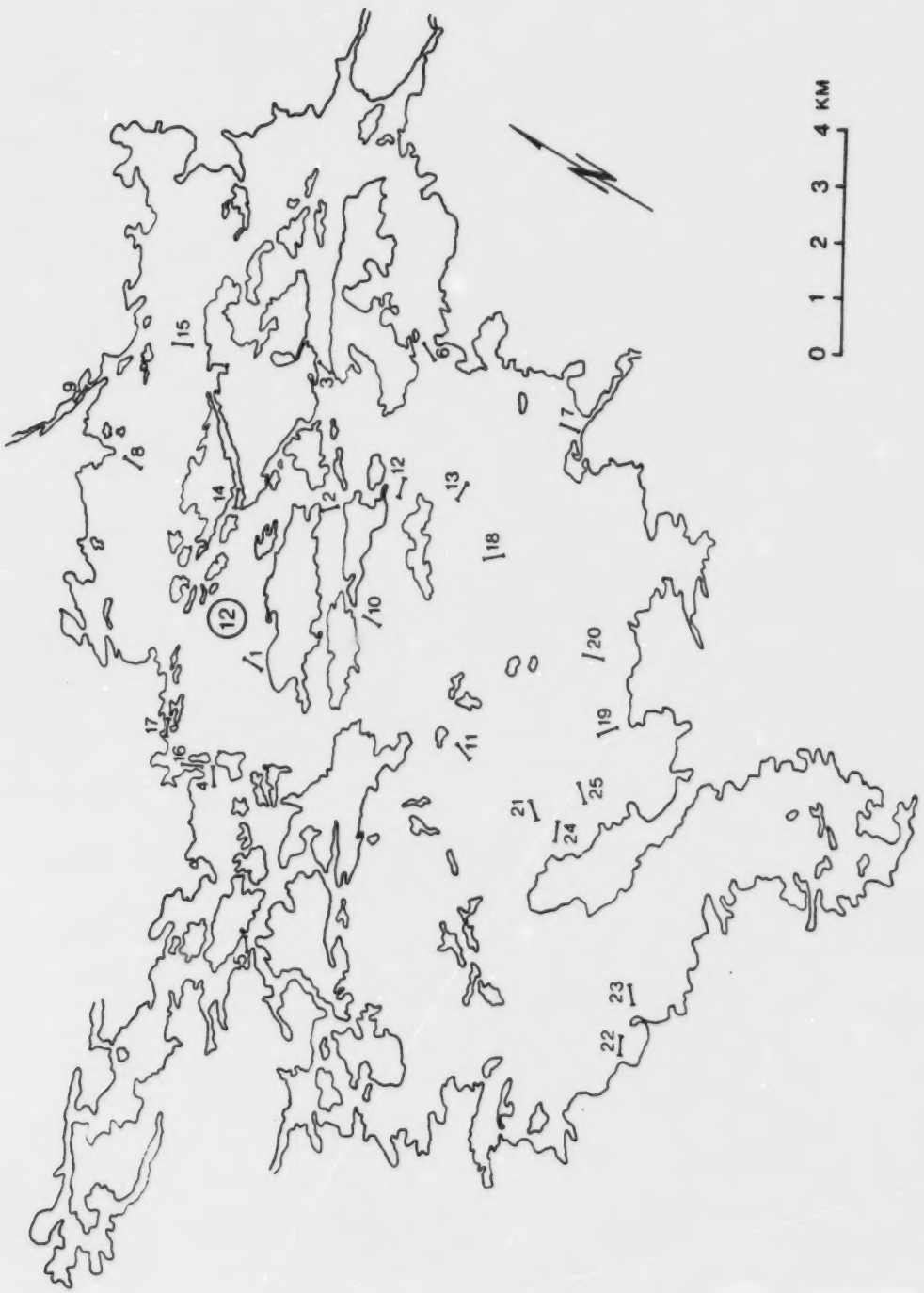


Fig. 7. Limnological station (circle) and netting locations (bars) in Walker Lake, 1981.

placed in 1.5 m of water, and recorded temperatures continuously at 30 cm above lake bottom. One thermograph was anchored near netting location # 49 in west Cross (Fig. 2), and the other was located at station 2 in east Cross (Fig. 5).

Plankton

Plankton were collected from the stations following the same sampling program as outlined for water condition measurements. A conical plankton net with an opening diameter of 25 cm and a mesh size of 73 µm was used. On each occasion, four hauls were made at each station with three used in dry weight determinations, and one for species identification and enumeration. The latter analyses have not been completed at the time of this writing.

Fresh plankton samples were vacuum-filtered through Gelman A/E glass fiber filters. Each filter had been pre-ignited at 500 C for 16 h and weighed before filtration. The filters with net plankton were dried at 105 C for 24 h and stored in a dessicator. The filters with net plankton were later weighed and plankton dry weights calculated.

Benthos

One benthos sample was collected monthly from all the stations (1 - 7, 9 - 12) using a 22 x 22 cm Ekman dredge. Samples were washed immediately with a 400 µm Nitex bag and preserved in 10%

formalin. Organisms were later identified and counted in the laboratory.

Experimental Fishing

The west and east basins of Cross Lake, Pipestone Lake and Walker Lake were fished with standard gang gill nets. Approximately 250 of each of the important commercial species, i.e. whitefish, walleye and pike, were sampled from each of the four areas. Each standard gang consisted of seven gill nets with mesh sizes, in order of set, of 3.8 cm (1.5 in.), 5.1 cm (2 in.), 7.6 cm (3 in.), 9.5 cm (3.75 in.), 10.8 cm (4.25 in.), 12.7 cm (5 in.), and 13.3 cm (5.25 in.). Each gill net was 22.9 m (25 yd.) in length and 1.8 m (6 ft.) deep with 6.1 m (20 ft.) bridles at each end. Gangs were set overnight for approximately 16 h. Efforts were made to sample a variety of habitat areas within the lakes.

The number of fish caught in each gill net was recorded for commercial and non-commercial species. Whitefish, walleye, pike, sauger *(Stizostedion canadense)* and cisco *(Coregonus artedii)* were sampled for fork length, weight, sex, maturity and stomach contents. For age determination, opercula were taken from pike, and otoliths from the other species. Otoliths were prepared and aged according to the procedures described by Erickson (1979). Opercula were cleansed of skin and aged using an illuminated magnifying glass.

In Walker Lake, commercially caught whitefish, walleye and pike (Appendices B27, B36 and B46, respectively) were combined with experimentally caught fish for determinations of ages at maturity for von Bertalanffy growth curves, and in the diet analyses.

Calculations

Procedures described by Snedecor and Cochran (1967) were followed for statistical analyses. Total mortality rates were computed according to Robson and Chapman (1961).

Maturity rate and age at maturity for walleyes were based on a logistic model described by Lysack (1980). The equation for this model is:

$$Y_x = \frac{K}{1 + e^{-b(x - x_o)}}$$

where Y_x = frequency of mature fish among all fish aged x.

K = frequency of mature fish among the oldest age groups (assumed K = 100%)

x_o = age at inflection point.

b = slope

This equation was transformed to the linear regression form of:

$$-\log_e \frac{(K - Y_x)}{Y_x} = bx_o - bx$$

This is a corrected version of the original transformation by Lysack (1980).

The mean weighted age at onset of sexual maturity (Z) was calculated by the equation:

$$Z = \frac{A_1K_1 + A_2 (K_2 - K_1) + A_3 (K_3 - K_2) + \ldots A_n (K_n - K_{n-1})}{K_1 + (K_2 - K_1) + (K_3 - K_2) + \ldots (K_n - K_{n-1})}$$

where A = age (years)

K_n = % of mature fish in the n^{th} age class.

This is a corrected form of Abrasov's (1967) original formula.

Fish growth was described by von Bertalanffy's (1938) equation:

$$l_t = L_\infty (1 - e^{-k (t - t_o)})$$

where l_t = length (mm) at age t (years)

L_∞ = asymptotic length (mm)

k = rate of decrease in length increments.

t_o = hypothetical age (years) at which the fish's length was zero.

Asymptotic length (L_∞) was determined from the plot of l_{t+1} vs l_t, as described by Walford (1946). L_∞ is the length at which the Walford line intersects a 45^o diagonal from the origin. The growth coefficient (k) was described by Brody (1927) and was the slope of the plot of $\log_e (L_\infty - l_t)$ vs t. The parameter t_o was calculated by the formula:

$$t_o = \frac{\log_e \frac{(L_\infty)}{b}}{k}$$

where b = length (mm) at age zero, based on Brody plot.

RESULTS

Lake Morphometry

Walker Lake had a net water area of 13025 ha and a mean depth of 4.9 m (Table 1). The lake had primarily a rocky shoreline with many submerged reefs. Islands were abundant with length of island shoreline being greater than the length of mainland shoreline.

Physical and Chemical Water Quality

Based on water condition characteristics records (Appendices A1 to A11), Secchi disc depths were, on the average, less than 0.70 m for Cross Lake (Table 2). Whiskey Jack basin in west Cross Lake was the only exception with an average Secchi disc transparency of 1.69 m. In general Secchi disc depth increased from the east to west basins of Cross Lake. Pipestone Lake had a greater Secchi disc depth than Cross Lake with Walker Lake the least turbid, having a mean Secchi depth of 2.78 m.

Bottom water temperatures between 20 and 21C were recorded in 9 out of 10 stations monitored in Cross and Pipestone lakes (Appendices A1 to A11). Daily maximum bottom water temperatures, recorded with Ryan thermographs, were above 20C for several consecutive days during July and August in west and east Cross Lake (Appendix A12).

Table 1. Morphometry of Walker Lake.

Parameter	Value
Area (ha)	13025
Maximum depth (m)	19
Mean depth (m)	4.9
Volume (X 10^7 m^3)	63.3
Length of shoreline (km)	240.3
Length of island shoreline (km)	299.5
Total length of shoreline (km)	539.8

Table 2 . Summary of water condition characteristics and plankton biomass for Cross, Pipestone and Walker lakes, 1981. Based on data in Appendices A[1] to A11 .

Area	Station Number	Mean depth (m)	Mean Secchi ± 2 S.D. (m)	Mean surface conductivity ± 2 S.D. (μmhos/cm)	Mean plankton biomass ± 2 S.E. (mg/m^3)
East Cross	1	1.9	0.40 ± 0.00	110 ± 13	479 ± 651
East Cross	2	1.5	0.51 ± 0.36	102 ± 42	518 ± 453
	3	7.1	0.60 ± 0.30	110 ± 59	304 ± 278
Middle Basin	4	2.1	0.53 ± 0.62	167 ± 111	380 ± 269
Middle Basin	5	1.9	0.49 ± 0.50	168 ± 156	246 ± 122
Sagatawak	6	1.8	0.65 ± 0.14	284 ± 48	117 ± 54
Sagatawak	7	4.8	0.67 ± 0.42	277 ± 66	90 ± 60
Jenpeg	9	3.1	0.57 ± 0.16	300 ± 43	136 ± 48
Whiskey Jack	10	8.1	1.69 ± 1.18	249 ± 45	349 ± 110
Pipestone	11	1.7	0.83 ± 0.50	271 ± 74	174 ± 179
Walker	12	6.6	2.78 ± 1.74	111 ± 16	397 ± 150

Summer dissolved oxygen concentrations were above 8 mg l^{-1} for 9 of 11 stations monitored on Cross, Pipestone and Walker lakes (Appendices A1 to A11). During August stations 3 and 10 (Cross Lake) had dissolved oxygen levels of 0 and 4.5 mg l^{-1} respectively near lake bottom.

Field conductivity measurements at each station tended to increase from June to the end of August (Appendices A1 to A11). Field conductivities were lower than the conductivities of the water samples determined by the Technical Services Laboratory (Appendices A13 to A18). However, field measurements also indicated higher conductivities for west Cross as compared to east Cross stations (Table 2).

Chemical analyses of water samples indicated wide variability in parameter values, particularly conductivity, TDS and pH, between monthly samples from stations 2 and 4 (Appendices A13 and A14). Limited variability between monthly measurements was found at stations 7, 10, 11 and 12 (Appendices A15 to A18). Means of these monthly measurements indicated that conductivity increased from east to west basins of Cross Lake (i.e. stations 2 to 10), while nutrient (nitrogen and phosphorous) and organic carbon concentrations decreased (Table 3). Pipestone Lake (station 11) had chemical parameter values which were similar to station 7 in Cross Lake, while Walker Lake (station 12) was similar to station 4.

Table 3 . Water chemistry of Cross, Pipestone and Walker lakes presented as summer means (June to Sept. 1981) of data in Appendices A13 to A18.

Parameter	Station					
	2	4	7	10	11	12
Conductivity (µmho /cm)	118	196	314	275	309	131
Total dissolved solids (mg/1)	90	137	203	184	204	93
Total suspended solids (mg/1)	34	19	20	<6	23	<5
pH	8.48	8.50	8.34	8.28	8.35	8.25
Alkalinity ($CaCO_3$)(mg/1)	48	65	105	93	104	66
Alkalinity (HCO_3)(mg/1)	54	72	125	112	122	78
Organic carbon - total (mg/1)	18.4	15.1	10.8	12.8	11.3	14.4
Organic carbon - dissolved (mg/1)	13.5	11.1	9.9	10.8	10.0	13.0
Phosphorus - total (mg/1)	0.06	0.07	0.04	0.04	0.04	0.03
Phosphorus - dissolved (mg/1)	0.02	0.04	0.02	0.02	0.02	<0.02
Nitrogen - total (mg/1)	0.98	0.83	0.50	0.50	0.45	0.53
Nitrogen - dissolved (mg/1)	0.73	0.63	0.50	0.45	0.45	0.45
Nitrate - Nitrite - dissolved(mg/1)	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphate - soluble (mg/1)	14.2	22.5	28.6	24.1	28.3	5.5
Chloride - soluble (mg/1)	<3.0	9.8	20.5	16.0	20.8	<2.0
Sodium - extractable (mg/1)	<8.8	<12.7	<17.3	14.3	21.0	<10.0
Calcium - extractable (mg/1)	15.8	19.3	29.8	26.0	29.5	19.5
Potassium - extractable (mg/1)	<1.5	<1.9	2.8	2.6	3.0	<1.8
Magnesium - extractable (mg/1)	<5.0	15.3	12.3	9.5	12.3	<5.8
Manganese - extractable (mg/1)	0.02	<0.02	0.02	<0.02	0.02	0.04
Iron - extractable (mg/1)	0.47	0.30	0.38	0.11	0.35	0.11
Silica - soluble reactive (mg/1)	0.5	1.2	5.0	3.3	1.2	2.3

Plankton

Peaks in plankton biomass in Cross Lake occurred for all stations in early July (Appendices A1 to A9). Plankton biomass in Pipestone Lake peaked during June (Appendix A10) whereas two biomass peaks were found for Walker Lake in June and September (Appendix A11). Mean plankton biomasses were similar for stations within the same basin, with biomass decreasing from east to west basin (Table 2). Pipestone Lake had a mean plankton biomass that was similar to the Sagatawak and Jenpeg basins, while Whiskey Jack and Walker Lake had levels closer to east Cross and the middle basin.

Benthos

Amphipoda, Chironomidae, Gastropoda and Pelecypoda were the predominant benthic organisms taken in Cross and Pipestone lakes (Table 4, Appendices A19 - A22). Chironomidae, Pelecypoda and Nematoda occurred most frequently in Walker Lake. Densities of benthos were < 3000 organisms m^{-2} at all stations in Cross and Pipestone lakes, with station 6 having the highest density. The density of benthos in Walker Lake was lower at approximately 2000 organisms m^{-2}.

Table 4. Mean density (number m^{-2}) of benthos in Cross and Pipestone lakes, based on data in Appendices A19 to A22.

Organism	Station										
	1	2	3	4	5	6	7	9	10	11	12
Annelida											
Hirudinea	51	38	14	24	14	67	14		5	24	5
Oligochaeta	19	76	344	53	62	5	5		511	124	53
Arthropoda											
Cladocera	89	5	72	5	5				19		5
Copepoda			5								
Amphipoda											
Hyalella azteca	1236	2882	67	96	5	5				5	10
Gammarus lacustris		5									
Pontoporeia hoyi						535	215	19		33	
Ostracoda	25	33	10	86	5			6	81		29
Acarina				5						5	
Diptera											
Ceratopogonidae		19	14	24	33	10	10	19	24	29	
Chaoboridae			5							19	38
Chironomidae	1829	1539	3853	2208	731	249	339	1001	2271	1075	908
Ephemeroptera											
Caenis											5
Hexagenia				5	244	153	177	452	76	272	
Hemiptera											
Corixidae			10	10		5					
Trichoptera	25	14		29	14	38		6	10	48	
Mollusca											
Gastropoda	19	43		182	1013	4030	1391	1249	153	1510	
Pelecypoda											
Sphaeriidae	76	191	139	153	1114	5478	1453	1096	378	2137	569
Unionidae						5	14	6			
Nematoda	433	153	186	139	1487	14			96	158	363
Total	3802	4998	4719	3019	4727	10594	3618	3854	3624	5439	1985

Fisheries

Species Composition and Catch per Unit of Effort

Experimental fishing in Walker, west Cross, east Cross and Pipestone lakes consisted of at least 25 standard gang net sets in each area (Appendices B2 to B5, respectively). Fourteen fish species were gill netted from Cross and Pipestone lakes, and eight species from Walker Lake (Table 5). Species composition varied in each basin of Cross Lake, but cisco and walleye predominated in Whiskey Jack, middle and east Cross basins. Walleye and white sucker occurred most frequently in Pipestone Lake catches, while white sucker and pike were most common in Walker Lake.

Of the four main basins (i.e. Jenpeg, Whiskey Jack, Sagatawak and middle) within west Cross Lake, catch per unit of effort (c.u.e.) was lowest in Jenpeg (sets 52 and 53; Appendix B3, Fig. 2), averaging 27 fish/set (Fig. 8). Pike comprised 32% of the catch, with walleye and white sucker each contributing 22% (Table 5).

Total c.u.e. of all species in Whiskey Jack (sets 33-38; Appendix B3, Fig. 3) was relatively high and averaged 126 fish/set. The predominant species caught was cisco, comprising 44% of the catch. In Cross Lake, Whiskey Jack basin had the highest c.u.e. of cisco (56 fish/set).

Table 5 . List of fish species gillnetted in Cross, Pipestone and Walker lakes, and their percent frequency of occurrence within each basin in 1981.

Species	West Cross				East Cross	Pipestone	Walker
	Jenpeg	Whiskey Jack	Sagatawak	Middle basin			
Lake whitefish *(Coregonus clupeaformis)*	3.7	2.9	7.7	6.3	6.3	3.8	8.0
Cisco *(Coregonus artedii)*	1.9	44.0	0.6	40.6	39.5	7.6	21.1
Northern pike *(Esox lucius)*	31.5	10.1	5.2	10.5	6.5	13.2	27.7
Walleye *(Stizostedion vitreum)*	22.2	19.3	6.7	30.6	35.0	24.0	7.5
Sauger *(Stizostedion canadense)*	1.9	0.8	10.1	0.9	0.1	1.3	1.6
Yellow perch *(Perca flavescens)*	9.3	16.7	2.5	0.3	0.3	6.0	2.0
White sucker *(Catostomus commersoni)*	22.2	6.2	46.6	7.6	10.8	19.6	30.3
Longnose sucker *(Catostomus catostomus)*			9.2		0.1	1.2	
Shorthead redhorse *(Moxostoma macrolepidotum)*	7.4		5.8	1.3	0.6	2.3	
Goldeye *(Hiodon alosoides)*					0.4	0.9	
Mooneye *(Hiodon tergisus)*			4.9	1.8	0.4	17.6	
Burbot *(Lota lota)*			0.3			0.5	1.7
Freshwater drum *(Aplodinotus grunniens)*			0.3	0.4	0.1	2.0	
Carp *(Cyprinus carpio)*					0.1	0.2	

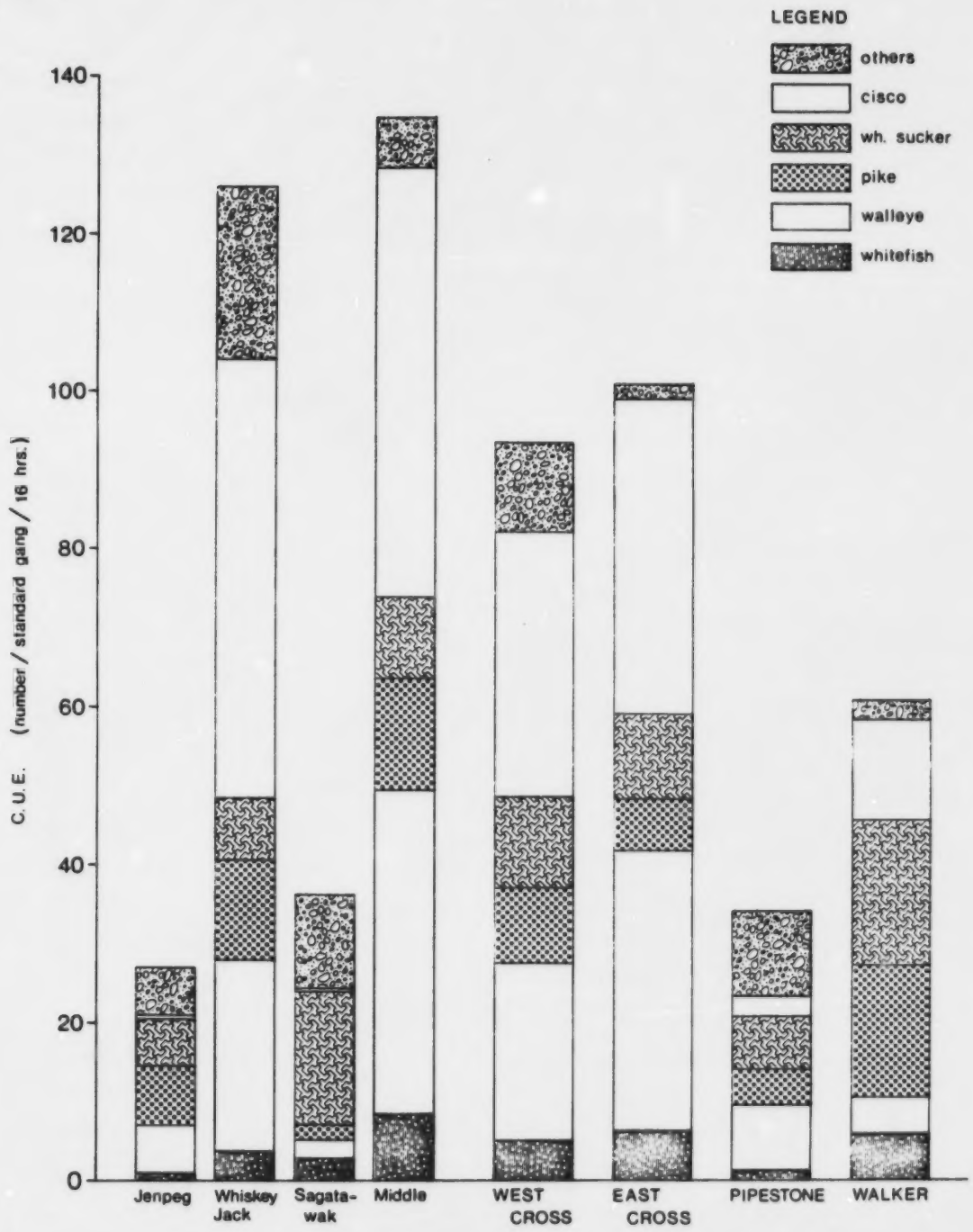


Fig. 8 . Catch per unit of effort for fish captured in Cross, Pipestone and Walker lakes in 1981. Jenpeg, Whiskey Jack, Sagatawak and Middle are basins within west Cross Lake.

Netting in Sagatawak (sets 26 - 32, 49, 50; Appendix B3, Fig. 2) was hampered by extreme amounts of algae (primarily *Spirogyra* and *Cladophora)* clogging the meshes. It is believed that this was a contributing factor in causing a low c.u.e. of 36 fish/set. The dominant species caught was white sucker (47%). In Cross Lake, the highest relative abundances of sauger (10%), whitefish (8%), mooneye (5%) as well as white sucker were found in the Sagatawak basin.

Catches in the middle basin (sets 39 - 48, 51; Appendix B3, Fig. 4) were the highest in Cross Lake at 135 fish/set. Cisco and walleye were most abundant having relative frequencies of 41 and 31% respectively. In comparison to all the basins in Cross Lake, middle basin had the highest c.u.e. for whitefish (8 fish/set), walleye (41) and pike (14).

Total c.u.e. of all species in east Cross Lake (sets 54 -78; Appendix B4, Fig. 5) was 101 fish/set, with cisco comprising 40% of the catch. Compared to the other basins in Cross Lake, walleye had the highest relative abundance in the east basin.

Walleye was the predominant species caught in Pipestone Lake (sets 79 - 106; Appendix B5, Fig. 6), having a relative abundance of 24%. Also dominating in the catch were white sucker (20%), mooneye (18%), and pike (13%). Total c.u.e. was low at 34 fish/set.

In Walker Lake (sets 1 - 25, Appendix B2; Fig. 7) the dominant species caught were white sucker (30%), pike (28%) and cisco (21%). Total c.u.e. of all species was 61 fish/set, with pike the highest at 17 fish/set.

In the west and east basins of Cross Lake, Pipestone Lake and Walker Lake, c.u.e. of whitefish increased with increasing mesh size, with the highest biomass per unit of effort in 12.7 cm (5 in.) mesh (Appendices B6 - B9). Except for the west basin of Cross Lake, the highest number of whitefish per unit of effort was found in 12.7 cm (5 in.) mesh. In west Cross, c.u.e. (number) in 10.8 cm (4.25 in.) mesh was slightly higher than 12.7 cm (5 in.) mesh.

The highest catches (numbers and biomass) per unit of effort of walleye in west Cross were found in 9.5 cm (3.75 in.) mesh (Appendix B10), while in east Cross and Walker lakes, 7.6 cm (3 in.) mesh produced the highest yield for a given effort (Appendices B11 and B13 respectively). In Pipestone Lake, 7.6 cm (3 in.) and 9.5 cm (3.75 in.) meshes had the highest c.u.e. of walleye in terms of numbers and biomass, respectively (Appendix B12).

C.U.E. in terms of numbers and biomass of pike were highest in 7.6 cm (3 in.) mesh in Cross, Pipestone and Walker lakes (Appendices B14 - B17). In all areas c.u.e. increased with increasing mesh size up to 7.6 cm (3 in.) mesh, then decreased with larger meshes.

In Whiskey Jack and Walker Lake 5.1 cm (2 in.) mesh had the highest number and biomass of cisco per unit of effort (Appendices B18 and B22 respectively). In the middle basin of west Cross Lake 5.1 cm (2 in.) mesh had the highest c.u.e.(number)

but 9.5 cm(3.75 in.) had the highest c.u.e. (biomass) (Appendix B19). In east Cross Lake c.u.e. (number) of cisco was highest in 7.6 cm (3 in.) mesh while c.u.e. (biomass) was greatest in 10.8 cm (4.25 in.) mesh (Appendix B20). C.U.E. (number and biomass)of cisco in Pipestone Lake was greatest in 7.6 cm (3 in.) mesh (Appendix B21).

Whitefish

Age Structure

The age structures of whitefish from west Cross, Pipestone and Walker lakes had a larger proportion of fish over age 7+ than was found in east Cross Lake (Fig. 9, Appendices B23 - B26). Very low frequencies of ages 4+ and 5+ were evident in Cross and Pipestone lakes, with high relative frequencies of ages 2+ and/or 3+.

In west Cross, modal age was 2+ (mean age = 9.29 years) with the mean ages of males and females being 8.98 and 9.53 years respectively (Table 6). Generally, mean age of the whitefish caught in each mesh increased with increasing mesh size (Appendix B6).

In east Cross modal age of the catch was 7+ (mean age = 7.90 years) with the mean age of males slightly younger than for females. Mean age of the catch in each mesh increased with increasing mesh size, with good representation of age 7+ in all meshes (Appendix B7).

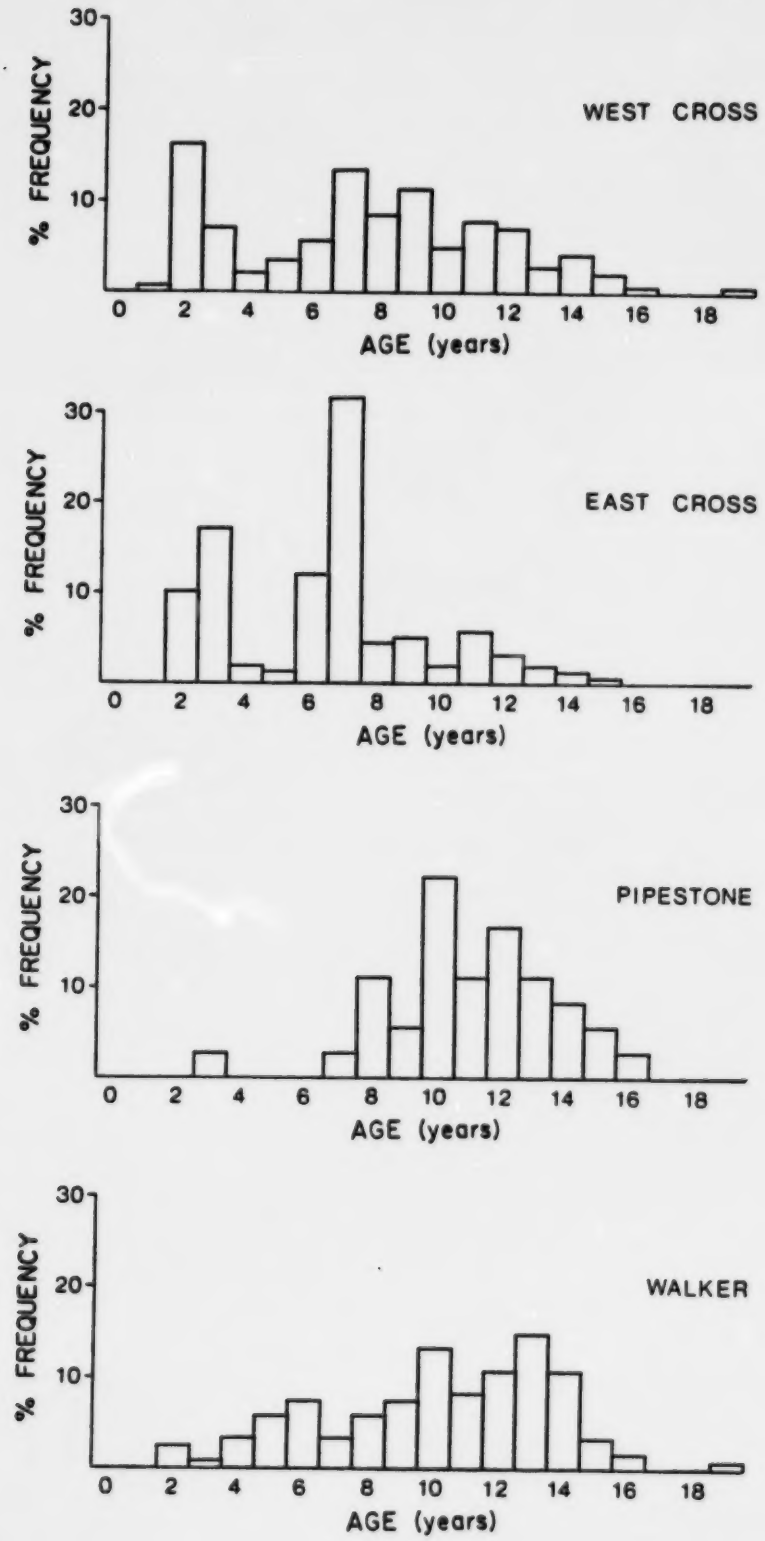


Fig. 9 . Age-frequencies of whitefish, 1981.

Table 6 . Growth parameters and mean weighted age of onset of sexual maturity for whitefish, 1981*.

Area	Sex	Mean age (years)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Mean age of maturity (years)
West Cross	Both	9.29	467	1732	1.66	5.93
	Males	8.98	460	1596	1.62	-
	Females	9.53	472	1845	1.70	6.25
East Cross	Both	7.90	478	2063	1.87	6.06
	Males	7.73	474	1932	1.80	-
	Females	8.07	482	2191	1.93	6.22
Pipestone	Both	11.23	488	2022	1.71	-
	Males	11.38	478	1875	1.67	-
	Females	11.14	494	2109	1.74	-
Walker	Both	10.45	473	1916	1.74	5.33
	Males	10.74	471	1891	1.75	5.11
	Females	10.08	474	1943	1.74	5.53

* because of bimodal age distribution, ages 1+ - 3+ were not used in calculations of the means.

The modal age of Pipestone Lake whitefish was 10+ (mean age = 11.23 years) with the mean age of males slightly older than for females. However, due to the small number of whitefish caught in Pipestone Lake (n = 36), the experimental sample may not be representative of the population.

In Walker Lake, the modal age was 13+ (mean age = 10.45 years) with the mean age of males greater than for females. Excluding 9.5 cm (3.75 in.) mesh, mean age of whitefish caught in each mesh increased with increasing mesh size (Appendix B9).

Mortality

Instantaneous mortality rates of whitefish from the west and east basins of Cross Lake were similar and slightly slower than the rates for Pipestone and Walker lakes (Table 7). Covariance tests on mortality rates indicated non-significant differences between lakes (Table 8). Mortality rates estimated by the Robson-Chapman method were higher than by regression analysis. Wide variation in the relative proportions of the age groups (Fig. 9), due to weak and strong year classes of whitefish, resulted in one non-significant (P = 0.05) mortality rate regression. Annual survival rates (regression method) were between 0.712 and 0.777 for the whitefish from the three lakes. In Walker Lake mortality rates were very similar between the commercial and experimental samples.

Table 7. Whitefish mortality and survival rates estimated by Robson-Chapman and regression methods.

Method	Area	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
Robson-Chapman	West Cross	8-16	0.313	0.269	0.731 ± 0.055	
	East Cross	8-15	0.329	0.280	0.720 ± 0.078	
	Pipestone	11-16	0.424	0.346	0.654 ± 0.129	
	Walker					
	- experimental	11-16	0.417	0.341	0.659 ± 0.072	
	- commercial	7-15	0.349	0.295	0.705 ± 0.053	
Regression	West Cross	8-16	0.271	0.237	0.763	0.743
	East Cross	8-15	0.252	0.223	0.777	0.657
	Pipestone	11-16	0.300	0.259	0.741	0.787
	Walker					
	- experimental	11-16	0.340	0.288	0.712	0.566*
	- commercial	7-15	0.301	0.260	0.740	0.733

* non-significant regression at P = 0.05

Table 8 . Covariance analyses of mortality and growth curves of whitefish (sexes combined), 1981.

Parameter	Comparison	Slopes		Elevations	
		F value (d.f.)	significance	F value (d.f.)	significance
Mortality (regression)	West Cross vs East Cross	0.04(1,13)	n.s.	6.95(1,14)*	
	West Cross vs Pipestone	0.06(1,11)	n.s.	2.05(1,12)	n.s.
	West Cross vs Walker	0.23(1,11)	n.s.	6.07(1,12)*	
	East Cross vs Pipestone	0.16(1,10)	n.s.	1.04(1,11)	n.s.
	East Cross vs Walker	0.33(1,10)	n.s.	16.57(1,11)*	
	Pipestone vs Walker	0.06(1, 8)	n.s.	13.73(1, 9)*	
Brody growth coefficients	West Cross vs East Cross	3.98(1,20)	n.s.	16.37(1,21)*	
	West Cross vs Walker	21.17(1,24)*		20.93(1,25)*	
	East Cross vs Walker	39.33(1,20)*		40.08(1,21)*	

* significance at P = 0.05

Growth

Positive allometric growth was exhibited by whitefish in Cross, Walker and except for females, in Pipestone lakes (Table 9). Condition of whitefish was highest in east Cross and lowest in west Cross (Table 6).

The von Bertalanffy model was used to describe the growth of whitefish in Cross and Walker lakes (sexes combined) (Figs. 10 and 11). Due to the small number of whitefish caught in Pipestone Lake growth was not described by a model. Parameters required in the von Bertalanffy model were determined by Walford plots (Appendices B28 and B30) and Brody plots (Appendices B29 and B30).

Whitefish attained similar asymptotic sizes in west Cross (523 mm), east Cross (531 mm) and Walker (538 mm) lakes (Table 10). However differences in Brody growth coefficients and t_o values resulted in significant differences in growths of whitefish between basins in Cross Lake, and between Cross and Walker lakes (Table 8). East Cross whitefish had, on the average, longer age-specific mean lengths than either Walker or west Cross whitefish (Appendices B23 - B27).

Maturity

The mean weighted age at onset of sexual maturity for female whitefish was 6.25 years in west Cross, 6.22 years in east Cross and 5.53 years in Walker Lake (Table 6). In Walker Lake mean age of maturity for males was slightly younger than for females. The mean ages of maturity for Pipestone whitefish

Table 9. Length-weight regressions for whitefish, 1981.

Area	Sex	Length-weight equation	n	r^2
West Cross	Both[a]	$\log_e$ weight = -12.65 + 3.267 $\log_e$ length	141	0.993
	Both[b]	$\log_e$ weight = -11.84 + 3.137 $\log_e$ length	17	0.998
	Males[b]	$\log_e$ weight = -12.40 + 3.223 $\log_e$ length	14	0.997
	Females[b]	$\log_e$ weight = -11.89 + 3.146 $\log_e$ length	16	0.997
East Cross	Both[a]	$\log_e$ weight = -12.46 + 3.254 $\log_e$ length	158	0.982
	Both[b]	$\log_e$ weight = -12.41 + 3.243 $\log_e$ length	14	0.995
	Males[b]	$\log_e$ weight = -12.41 + 3.241 $\log_e$ length	11	0.999
	Females[b]	$\log_e$ weight = -12.27 + 3.225 $\log_e$ length	13	0.993
Pipestone	Both[a]	$\log_e$ weight = -13.28 + 3.364 $\log_e$ length	36	0.948
	Both[b]	$\log_e$ weight = -13.24 + 3.365 $\log_e$ length	11	0.972
	Males[b]	$\log_e$ weight = -13.28 + 3.362 $\log_e$ length	10	0.968
	Females[b]	$\log_e$ weight = - 8.80 + 2.653 $\log_e$ length	6	0.802
Walker	Both[a]	$\log_e$ weight = -12.30 + 3.219 $\log_e$ length	296	0.979
	Both[b]	$\log_e$ weight = -12.57 + 3.266 $\log_e$ length	17	0.998
	Males[b]	$\log_e$ weight = -12.72 + 3.291 $\log_e$ length	17	0.997
	Females[b]	$\log_e$ weight = -11.83 + 3.144 $\log_e$ length	12	0.998

a calculated using individual lengths and weights from all sampled fish

b calculated using age-specific mean lengths and weights

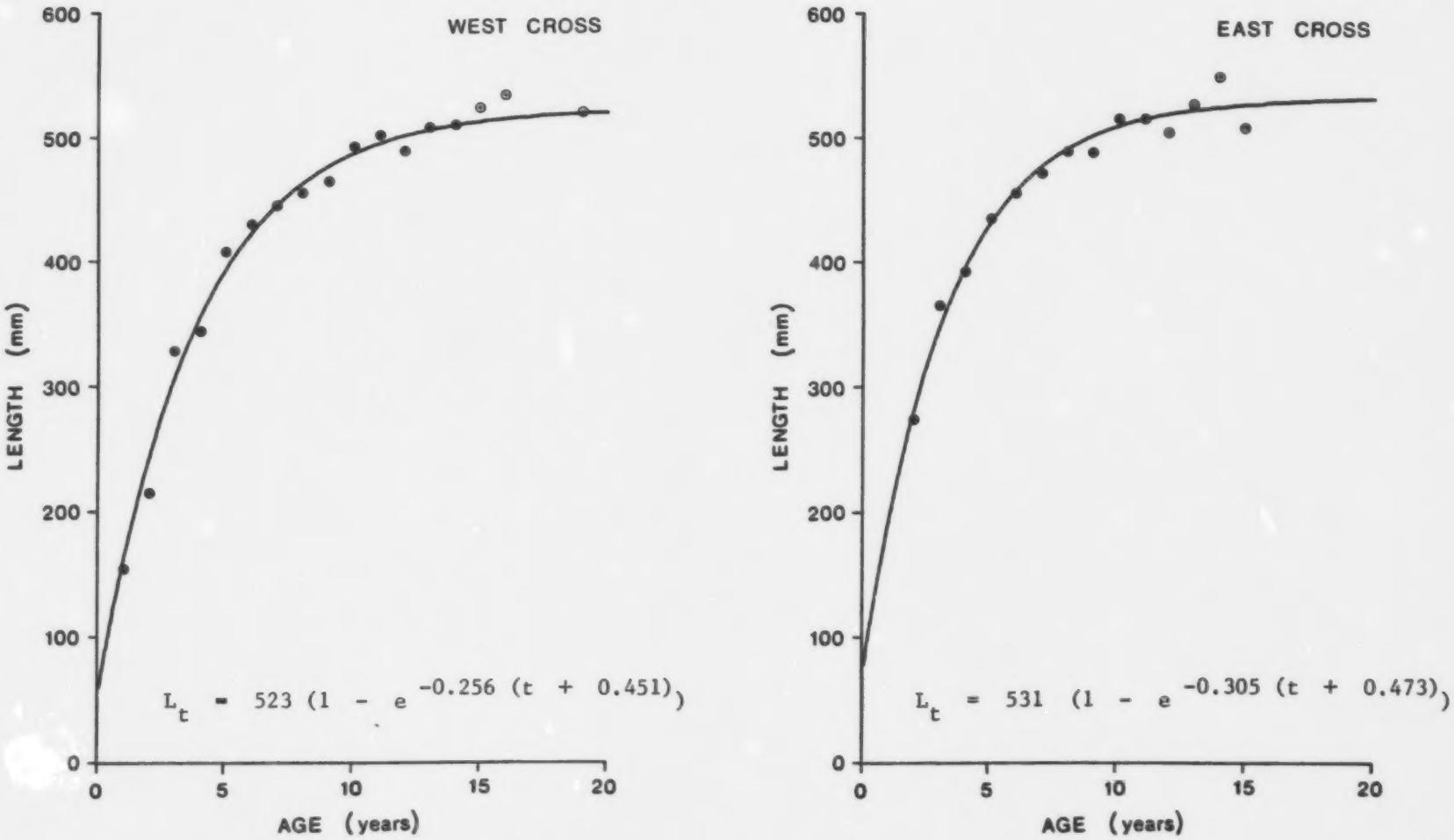


Fig. 10. Von Bertalanffy growth curves for whitefish from the west and east basins of Cross Lake, 1981.

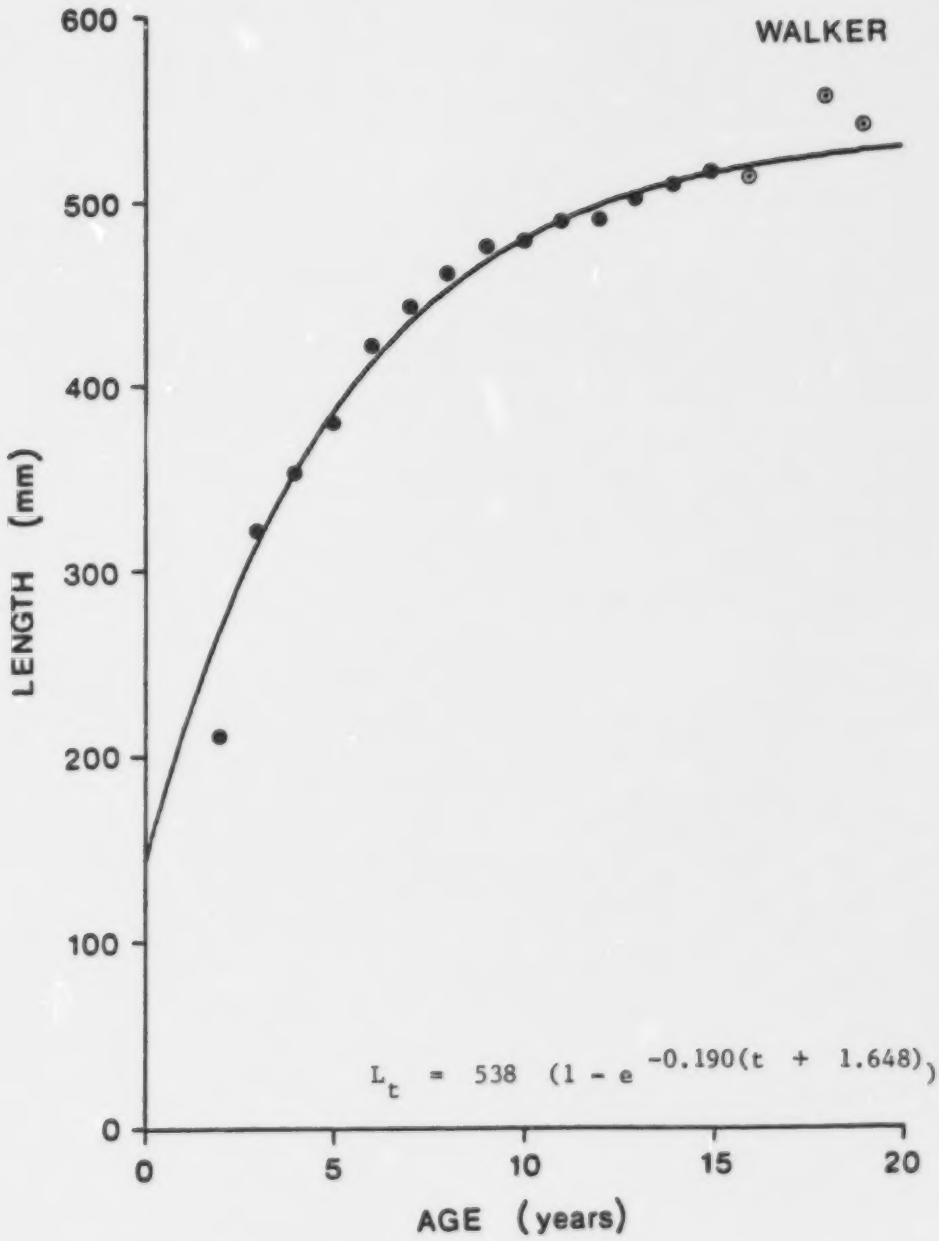


Fig. 11. Von Bertalanffy growth curves for whitefish from Walker Lake, 1981.

Table 10. Coefficients used in von Bertalanffy model of whitefish growth, 1981.

Area	Ages used	Brody growth coefficient	Asymptotic length (mm)	t_o (years)	r^2 of Brody plot
West Cross	1-14	0.256	523	-0.451	0.972
East Cross	2-11	0.305	531	-0.473	0.965
Walker	2-15	0.190	538	-1.648	0.985

and male whitefish from Cross Lake could not be calculated because few younger whitefish were caught (Appendix B31).

Diet

A higher proportion of the whitefish stomachs contained food in east Cross (70%) as compared to west Cross (28%) (Table 11). In west Cross whitefish ingested primarily Gastropoda, Pelecypoda and Trichoptera, while east Cross whitefish concentrated on Amphipoda, as well as Chironomidae and Pelecypoda. In Pipestone Lake, whitefish fed mainly on Pelecypoda, Gastropoda and Hemiptera. The majority of Walker Lake whitefish were feeding on Pelecypoda and Chironomidae.

Walleye

Age Structure

Age-frequencies of walleye from Cross, Pipestone and Walker lakes were similar (Fig. 12). In east Cross and Pipestone lakes a strong year class was evident at age 7+, with apparently weak year classes at ages 9+ and 10+. In Cross and Pipestone lakes, ages 3+ and 4+ were less abundant than age 2+. Apparent in all lakes was the high relative abundances of age 11+ (1970 year class).

The modal age of walleye in west Cross and Walker lakes was 11+, with similar mean ages of 9.63 and 9.65 years respectively (Appendices B32 and B35, Table 12). Walleye in east Cross and

Table 11 . Whitefish stomach contents ,1981 . The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	West Cross	East Cross	Pipestone	Walker
Number examined	141	155	35	168
Number containg food	40	109	35	151
Hirudinea	7.5(3)		2.9(1)	1.3(2)
Gastropoda	50.0(20)	10.1(11)	68.6(24)	4.6(7)
Pelecypoda	30.0(12)	24.8(27)	71.4(25)	82.1(124)
Hydrocarina	5.0(2)	0.9(1)		0.7(1)
Cladocera		2.8(3)		
Amphipoda	2.5(1)	80.7(88)	17.1(6)	12.6(19)
Ephemeroptera	10.0(4)		20.0(7)	2.6(4)
Hemiptera	12.5(5)	18.3(20)	57.1(20)	8.6(13)
Trichoptera	30.0(12)	3.7(4)	11.4(4)	
Chironomidae	7.5(3)	34.9(38)	2.9(1)	79.5(120)
Plants	2.5(1)	1.8(2)		4.0(6)
Unidentified	7.5(3)			1.3(2)

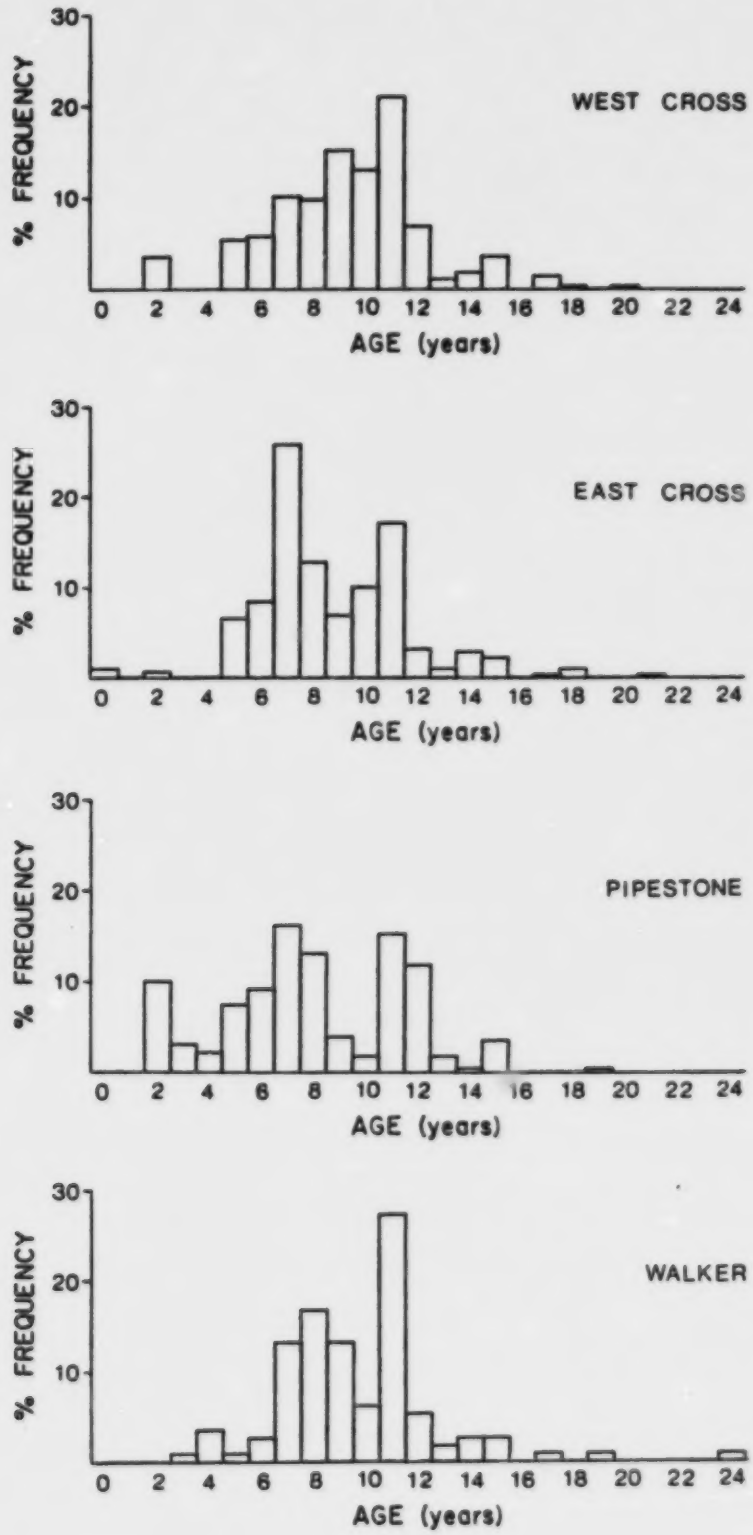


Fig. 12. Age-frequencies of walleyes, 1981.

Table 12. Growth parameters for walleye, 1981*.

Area	Sex	Mean age (years)	Mean length (mm)	Mean weight (g)	Mean cond. factor
West Cross	Both	9.63	411	791	1.11
	Males	9.91	398	719	1.11
	Females	9.46	420	835	1.10
East Cross	Both	8.83	387	666	1.12
	Males	8.84	375	614	1.14
	Females	8.82	397	709	1.11
Pipestone	Both	8.67	387	694	1.14
	Males	8.96	372	612	1.13
	Females	8.50	396	742	1.14
Walker	Both	9.65	420	902	1.14
	Males	9.72	397	741	1.13
	Females	9.61	433	985	1.14

* because of bimodal age distribution, ages 0+ - 2+ were not used in calculations of the means.

Pipestone lakes had a modal age of 7+, and mean ages of 8.83 and 8.67 years respectively (Appendices B33 and B34). In all areas mean age of males was older than for females.

Mortality

Robson--Chapman and regression estimates indicated higher mortality rates for west Cross than for east Cross walleyes (Table 13). Pipestone and Walker lakes had walleye mortality rate estimates which were similar to those for east Cross Lake. In all tests using covariance analysis, mortality rates between lakes were not significantly different (Table 14). For all areas, survival rate estimates ranged from 0.632 to 0.737 (regression method). Survival rates of Walker Lake walleye were similar between the experimental and commercial samples. Wide variation in the relative proportions of the age groups (Fig. 12), due to weak and strong year classes of walleye, resulted in three non-significant mortality rate relationships ($P = 0.05$).

Growth

Except for west Cross Lake, the length-weight regressions indicated negative allometric growth for walleye (Table 15). West Cross walleye exhibited isometric or slightly positive allometric growth. Condition factors of walleye ranged from 1.10 to 1.14, and were similar between lakes and between sexes (Table 12).

Von Bertalanffy growth curves for walleye (sexes combined) (Figs. 13 and 14) were drawn based on Walford plots (Appendices B37 and B38) and Brody regressions (Appendices B39 and B40). Asymptotic

Table 13. Walleye mortality and survival rates estimated by Robson-Chapman and regression methods.

Method	Area	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
Robson-Chapman	West Cross	10-15	0.555	0.426	0.574 ± 0.057	
	East Cross	8-15	0.361	0.303	0.697 ± 0.038	
	Pipestone	8-14	0.355	0.299	0.701 ± 0.048	
	Walker					
	- experimental	9-15	0.416	0.340	0.660 ± 0.068	
	- commercial	9-17	0.428	0.348	0.652 ± 0.042	
Regression	West Cross	10-15	0.446	0.360	0.640	0.532*
	East Cross	8-15	0.305	0.263	0.737	0.558
	Pipestone	8-14	0.354	0.298	0.702	0.330*
	Walker					
	- experimental	9-15	0.331	0.282	0.718	0.536*
	- commercial	9-17	0.459	0.368	0.632	0.768

* regressions are non-significant at P = 0.05

Table 14. Covariance analyses of mortality and growth curves of walleye (sexes combined), 1981.

Parameter	Comparison	Slopes		Elevations	
		F value (d.f.)	significance	F value (d.f.)	significance
Mortality rate (regression)	West Cross vs East Cross	0.40(1,10)	n.s.	0.27(1,11)	n.s.
	West Cross vs Pipestone	0.08(1, 9)	n.s.	2.76(1,10)	n.s.
	West Cross vs Walker	0.22(1, 9)	n.s.	5.02(1,10)	*
	East Cross vs Pipestone	0.04(1,11)	n.s	2.21(1,12)	n.s.
	Pipestone vs Walker	0.008(1,10)	n.s.	0.0002(1,11)	n.s.
Brody growth coefficient	West Cross vs East Cross	8.62(1,18)	*	13.51(1,19)	*
	West Cross vs Pipestone	0.07(1,17)	n.s.	2.11(1,18)	n.s.
	West Cross vs Walker	5.61(1,17)	*	69.76(1,18)	*
	East Cross vs Pipestone	10.74(1,19)	*	19.20(1,20)	*
	East Cross vs Walker	0.31(1,19)	n.s.	56.52(1,20)	*
	Pipestone vs Walker	6.97(1,18)	*	76.52(1,19)	*

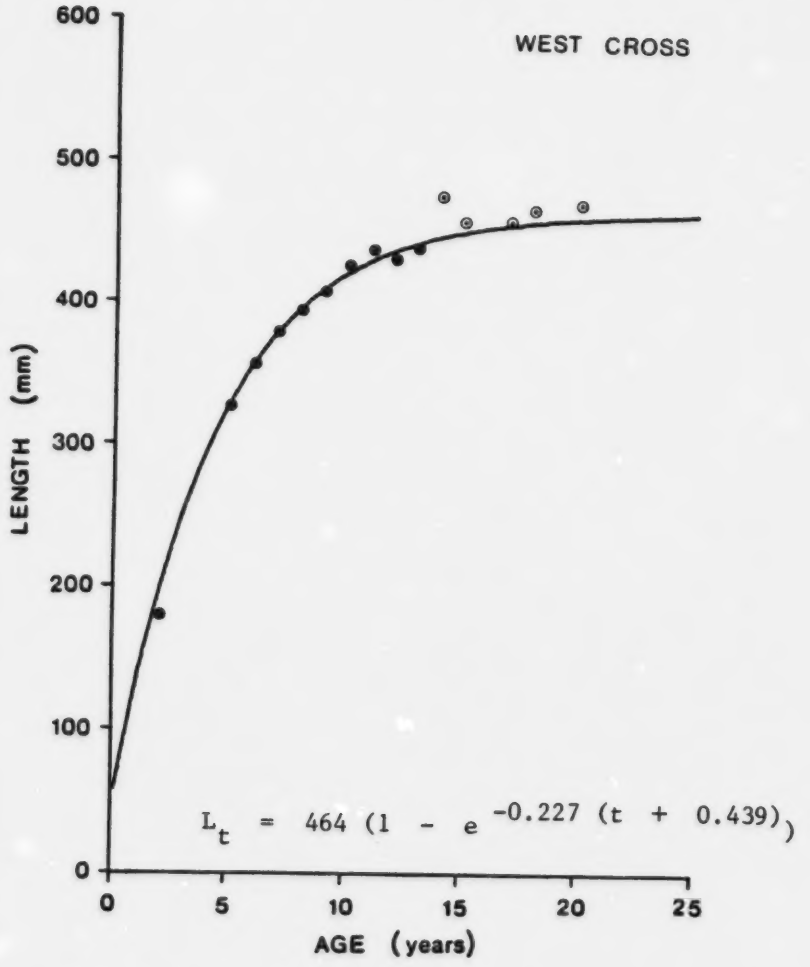
* significance at P = 0.05

Table 15. Length-weight regression for walleye, 1981.

Area	Sex	Length-weight equation	n	r^2
West Cross	Both[a]	$\log_e$ weight = -11.54 + 3.021 $\log_e$ length	275	0.984
	Both[b]	$\log_e$ weight = -11.51 + 3.016 $\log_e$ length	15	0.999
	Males[b]	$\log_e$ weight = -11.48 + 3.011 $\log_e$ length	15	0.999
	Females[b]	$\log_e$ weight = -11.42 + 3.000 $\log_e$ length	12	0.999
East Cross	Both[a]	$\log_e$ weight = - 9.33 + 2.653 $\log_e$ length	322	0.987
	Both[b]	$\log_e$ weight = - 9.30 + 2.651 $\log_e$ length	16	0.998
	Males[b]	$\log_e$ weight = -10.93 + 2.925 $\log_e$ length	14	0.983
	Females[b]	$\log_e$ weight = -10.26 + 2.808 $\log_e$ length	12	0.999
Pipestone	Both[a]	$\log_e$ weight = -10.87 + 2.913 $\log_e$ length	229	0.985
	Both[b]	$\log_e$ weight = -10.93 + 2.926 $\log_e$ length	15	0.999
	Males[b]	$\log_e$ weight = -10.99 + 2.934 $\log_e$ length	14	0.998
	Females[b]	$\log_e$ weight = -10.97 + 2.933 $\log_e$ length	13	0.999
Walker	Both[a]	$\log_e$ weight = - 9.97 + 2.762 $\log_e$ length	334	0.954
	Both[b]	$\log_e$ weight = -10.96 + 2.926 $\log_e$ length	19	0.993
	Males[b]	$\log_e$ weight = -10.41 + 2.832 $\log_e$ length	14	0.995
	Females[b]	$\log_e$ weight = -11.01 + 2.933 $\log_e$ length	16	0.989

a calculated using individual lengths and weights from all sampled fish

b calculated using age-specific mean lengths and weights



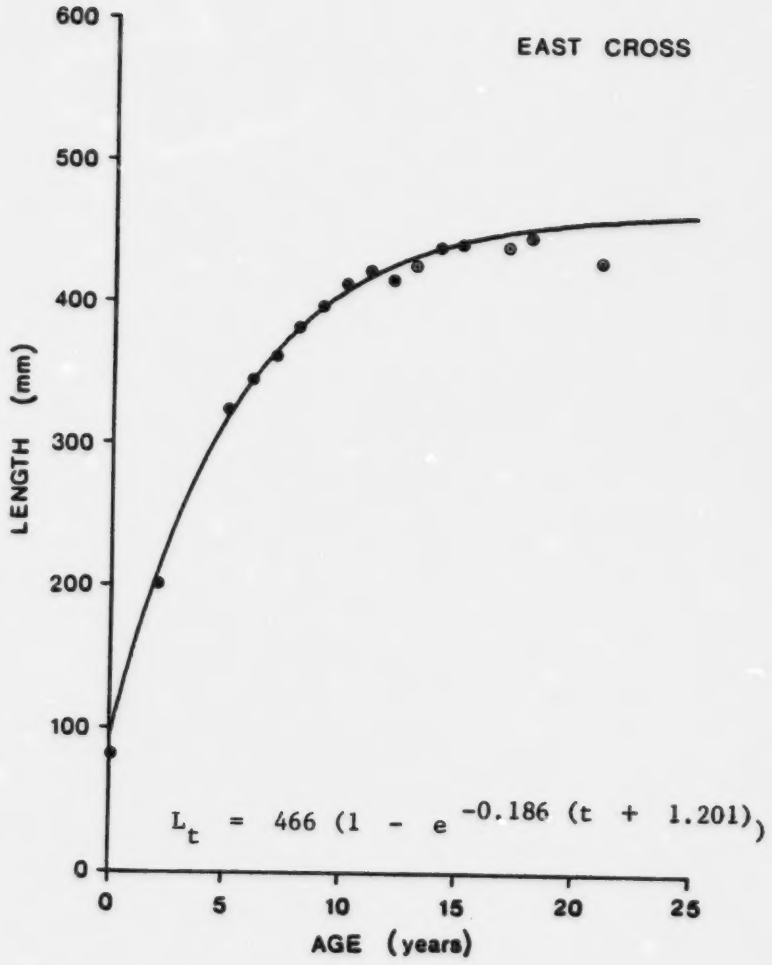


Fig. 13. Von Bertalanffy growth curves for walleye from the west and east basins of Cross Lake, 1981.

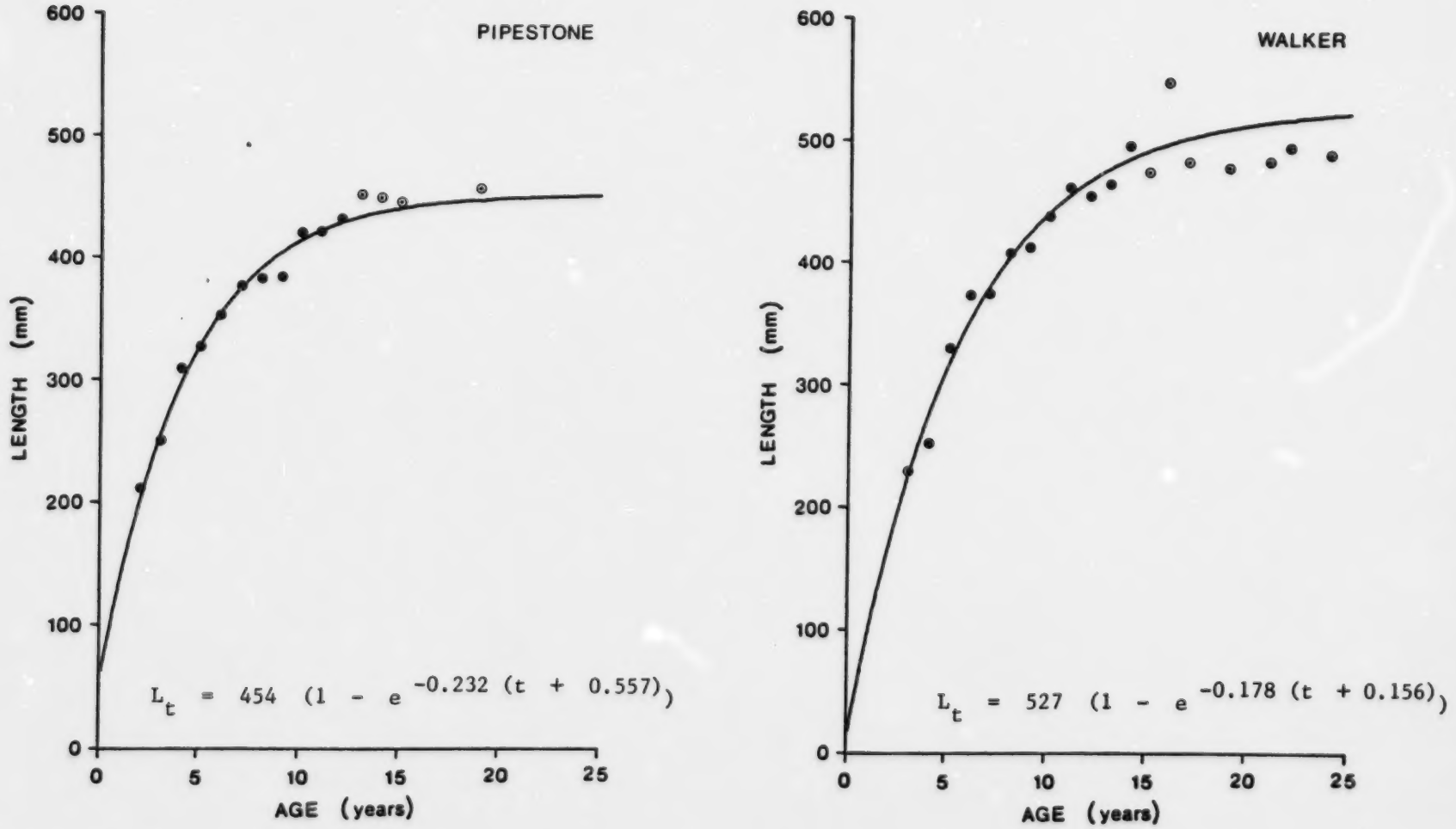


Fig. 14 . Von Bertalanffy growth curves for walleye from Pipestone and Walker lakes, 1981.

lengths of walleye were similar in west Cross (464 mm) and east Cross (466 mm) lakes, highest in Walker Lake (527 mm) and lowest in Pipestone Lake (454 mm) (Table 16). West Cross and Pipestone walleye had similar Brody growth coefficients, asymptotic lengths and t_o values, and consequently growths that were not significantly different (Table 14). Significant differences in walleye growth were found in the other comparisons between west Cross, east Cross, Pipestone and Walker lakes.

Maturity

In Cross and Walker lakes, the mean ages of walleye at maturity, calculated using Abrasov's (1967) method, were higher than the mean ages of maturity represented by the inflection point of the maturity rate equation. (Table 17, Appendix B41). Conversely in Pipestone Lake the inflection points were up to one year older than the ages determined using Abrasov's method. Based on the regression method, female walleye reached sexual maturity at similar ages in west and east Cross Lake (7.3 years), with Walker Lake females maturing at 8.7 years and Pipestone Lake females at 10.4 years. In all lakes male walleye were younger than females at maturity.

Diet

Unidentified fish remains predominated in the walleye stomachs examined in Cross, Pipestone and Walker lakes (Table 18). Forage fish occurring frequently in the stomachs were yellow perch, shiners, and sticklebacks. Invertebrates occurred in more than 20% of the stomachs examined from each lake. The most predominant

Table 16. Coefficients used in von Bertalanffy model of walleye growth, 1981.

Area	Ages used	Brody growth coefficient	Asymptotic length (mm)	t_o (years)	r^2 of Brody plot
West Cross	2,5-13	0.227	464	-0.439	0.969
East Cross	0,2,5-12, 14,15	0.186	466	-1.201	0.990
Pipestone	2-12	0.232	454	-0.557	0.967
Walker	4-14	0.178	527	-0.156	0.941

Table 17. Maturity rate equations and mean weighted age of onset of sexual maturity in walleye, 1981.

Area	Sex	$\log_e \frac{(k-y)}{y} = bx_o - bx$ Regression	r^2	Inflection point - x_o (yrs)	Mean age of maturity (years)
West Cross	Both	Y = 10.471 - 1.459x	0.938	7.18	7.63
	Males	Y = 7.540 - 1.131x*	0.991	6.67	7.44
	Females	Y = 11.015 - 1.508x	0.963	7.30	7.76
East Cross	Both	Y = 6.792 - 1.010x	0.912	6.72	7.48
	Males	Y = 3.183 - 0.521x*	0.799	6.11	7.01
	Females	Y = 9.866 - 1.348x	0.971	7.32	7.89
Pipestone	Both	Y = 6.392 - 0.705x	0.941	9.07	8.84
	Males	Y = 5.082 - 0.658x*	0.655	7.72	7.64
	Females	Y = 6.155 - 0.590x*	0.838	10.43	9.38
Walker	Both	Y = 11.248 - 1.322x	0.953	8.51	9.03
	Males	Y = 9.693 - 1.199x*	0.836	8.08	8.52
	Females	Y = 11.118 - 1.274x	0.953	8.73	9.22

* these regressions are non-significant at P = 0.05. All other regressions are significant.

Table 18 . Walleye stomach contents, 1981. The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	West Cross	East Cross	Pipestone	Walker
Number examined	265	318	229	111
Number containing food	116	125	130	76
Fish	81.9(95)	80.0(100)	93.1(121)	84.2(64)
Cisco	0.9(1)			6.6(5)
White sucker			3.1(4)	1.3(1)
Perch	4.3(5)	12.0(15)	12.3(16)	1.3(1)
Burbot			0.8(1)	
Trout-perch	0.9(1)		3.1(4)	
Shiners	1.7(2)	4.0(5)	13.8(18)	2.6(2)
Sticklebacks		0.8(1)	13.8(18)	14.5(11)
Johnny darter	0.9(1)	0.8(1)	0.8(1)	
Sculpin				3.9(3)
Freshwater Drum			0.8(1)	
Unidentified	73.3(85)	64.8(81)	59.2(77)	61.8(47)
Invertebrates	39.7(46)	27.2(34)	22.3(29)	36.8(28)
Hirudinea	6.9(8)	6.4(8)	2.3(3)	1.3(1)
Pelecypoda			1.5(2)	
Amphipoda		4.0(5)		1.3(1)
Decapoda	0.9(1)	0.8(1)		
Ephemeroptera	19.0(22)		18.5(24)	19.7(15)
Hemiptera		5.6(7)		
Coleoptera		1.6(2)		
Diptera	0.9(1)	4.8(6)		
Chironomidae	19.8(23)	10.4(13)		18.4(14)
Plants		3.2(4)	0.8(1)	

invertebrates were Ephemeroptera (mayflies) and Chironomidae (midges).

Pike

Age Structure

Similar age structures of pike were found for west Cross and Pipestone lakes. In comparison, East Cross had a higher proportion of younger fish and Walker Lake had a higher proportion of older fish (Fig. 15, Appendices B42 - B45). Modal ages of the pike populations were 4+ in east Cross (mean age = 4.90), 6+ in west Cross (mean age = 5.95) and Pipestone (mean age = 6.12) lakes, and 8+ in Walker Lake (mean age = 7.60) (Table 19). Mean ages of male pike were less than for females in each area fished.

Mortality

Instantaneous mortality rates were similar for west Cross, east Cross and Walker lakes pike, but lower for pike from Pipestone Lake (Table 20). Except for the Walker Lake experimental sample, regression estimates were lower than the rates obtained by the Robson-Chapman method. In Walker Lake estimates of mortality rate by the Robson-Chapman method gave similar results for both the commercial and experimental samples. These estimates were also similar to the rate determined using regression analysis on the experimental sample. However mortality rate analysis on the commercial pike sample resulted in a highly non-significant regression ($F = 1.71$) at $P = 0.05$ and a much lower rate. Covariance analyses of mortality rates indicated non-significant differences between the lakes (Table 21).

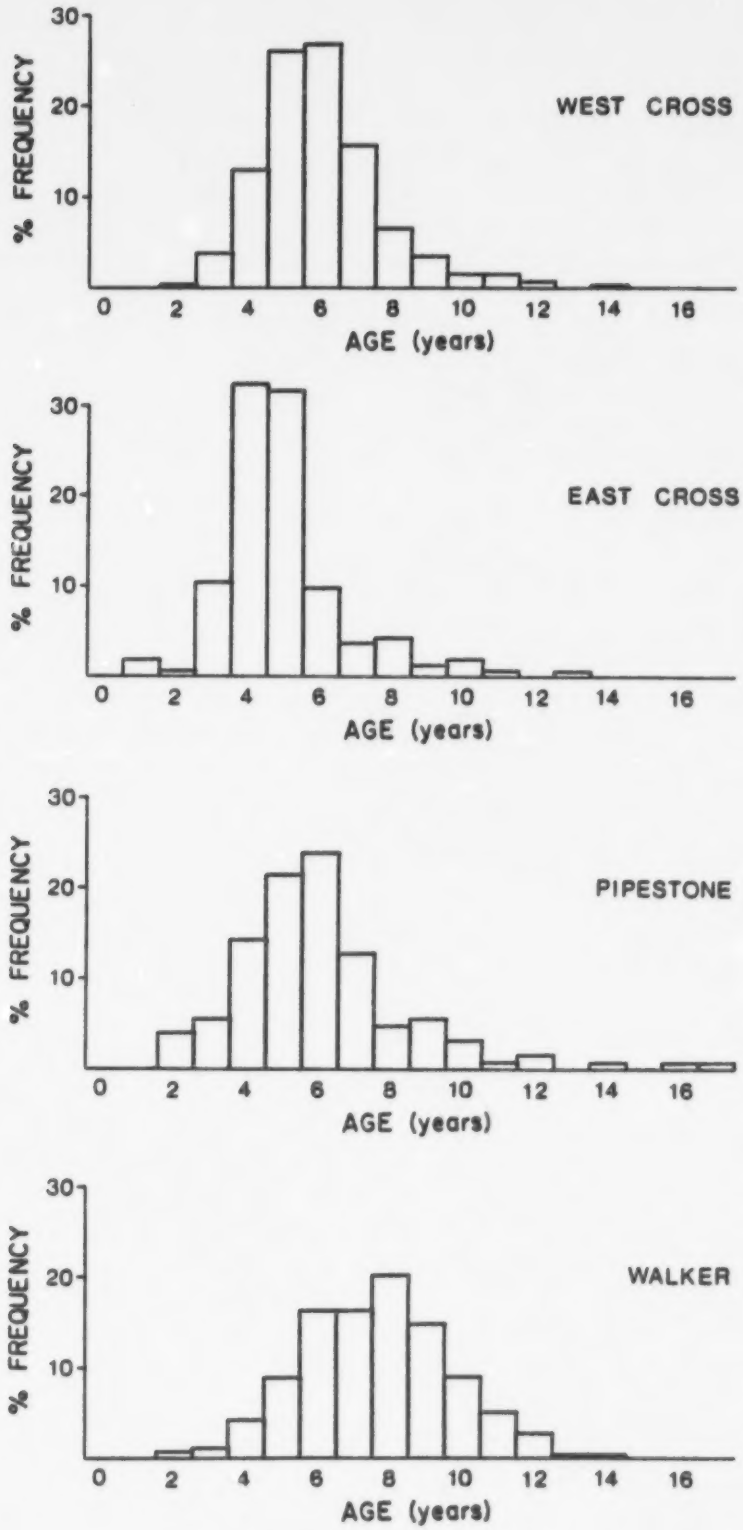


Fig. 15. Age-frequencies of pike, 1981.

Table 19. Growth parameters and mean weighted age of onset of sexual maturity for pike, 1981.

Area	Sex	Mean age (years)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Mean age of maturity (years)
West Cross	Both	5.95	531	1060	0.66	4.05
	Males	5.82	510	916	0.67	4.08
	Females	6.02	542	1135	0.65	4.14
East Cross	Both	4.90	499	860	0.64	3.49
	Males	4.57	470	720	0.66	3.30
	Females	5.06	513	928	0.63	3.81
Pipestone	Both	6.12	547	1351	0.67	
	Males	4.95	477	829	0.68	-
	Females	6.55	578	1585	0.67	3.50
Walker	Both	7.60	600	1488	0.66	4.36
	Males	7.11	557	1177	0.66	4.00
	Females	7.78	615	1603	0.66	4.63

Table 20. Pike mortality and survival rates estimated by Robson-Chapman and regression methods.

Method	Area	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
Robson-Chapman	West Cross	7-12	0.713	0.510	0.490 ± 0.082	
	East Cross	5-11	0.743	0.524	0.476 ± 0.078	
	Pipestone	7-12	0.566	0.432	0.568 ± 0.111	
	Walker					
	- experimental	9-14	0.712	0.509	0.491 ± 0.079	
	- commercial	11-14	0.724	0.515	0.485 ± 0.177	
Regression	West Cross	7-12	0.579	0.440	0.560	0.957
	East Cross	5-11	0.582	0.441	0.559	0.901
	Pipestone	7-12	0.467	0.373	0.627	0.796
	Walker					
	- experimental	9-14	0.806	0.553	0.447	0.931
	- commercial	11-14	0.491	0.388	0.612	0.461*

* non-significant regression at P = 0.05

Table 21. Covariance analyses of mortality and growth curves of pike (sexes combined), 1981.

Parameter	Comparison	Slopes F value (d.f.)	significance	Elevations F value (d.f.)	significance
Mortality (regression)	West Cross vs East Cross	0.0008(1,9)	n.s.	24.81(1,10)	*
	West Cross vs Pipestone	0.71 (1,8)	n.s.	7.27(1, 9)	*
	West Cross vs Walker	3.29 (1,8)	n.s.	19.63(1, 9)	*
	East Cross vs Pipestone	0.64 (1,9)	n.s.	3.06(1,10)	n.s.
	East Cross vs Walker	2.58 (1,9)	n.s.	43.49(1,10)	*
	Pipestone vs Walker	4.44 (1,8)	n.s.	21.12(1, 9)	*
Brody growth coefficient	West Cross vs East Cross	7.95 (1,18)	*	28.97(1,19)	*
	West Cross vs Pipestone	9.41 (1,17)	*	23.05(1,18)	*
	West Cross vs Walker	0.21 (1,17)	n.s.	3.08(1,18)	n.s.
	East Cross vs Pipestone	0.27 (1,17)	n.s.	4.14(1,18)	n.s.
	East Cross vs Walker	32.64 (1,17)	*	73.23(1,18)	*
	Pipestone vs Walker	80.45 (1,16)	*	68.03(1,17)	*

* significance at P = 0.05

Growth

Negative allometric growth was exhibited by pike in east Cross and Walker lakes, while length-weight regressions for pike in west Cross and Pipestone lakes indicated positive (slope > 3) allometric growth (Table 22). Condition factors for pike ranged from 0.63 to 0.68, and were similar between lakes and between sexes (Table 19).

The growth of pike (sexes combined) was described using the von Bertalanffy model (Figs. 16 and 17, Table 23). Parameters required in the model were provided by Walford plots (Appendices B47 and B48) and Brody regressions (Appendices B49 and B50). Pike in west Cross and Walker lakes had similar asymptotic lengths and were growing at similar rates (Table 21). Pipestone and east Cross pike also had asymptotic lengths and growth rates which were not significantly different.

Maturity

Based on Abrasov's (1967) method, the mean age at maturity of female pike was 3.50 years in Pipestone, 3.81 years in east Cross, 4.14 years in west Cross and 4.63 years in Walker (Table 19, Appendix B51). Generally males were slightly younger than females at maturity.

Table 22. Length-weight regressions for pike, 1981.

Area	Sex	Length-weight equation	n	r^2
West Cross	Both[a]	$\log_e$ weight = -12.85 + 3.147 $\log_e$ length	261	0.954
	Both[b]	$\log_e$ weight = -13.72 + 3.297 $\log_e$ length	12	0.986
	Males[b]	$\log_e$ weight = -12.21 + 3.052 $\log_e$ length	9	0.991
	Females[b]	$\log_e$ weight = -13.59 + 3.274 $\log_e$ length	12	0.988
East Cross	Both[a]	$\log_e$ weight = -10.82 + 2.814 $\log_e$ length	163	0.965
	Both[b]	$\log_e$ weight = -11.28 + 2.905 $\log_e$ length	12	0.993
	Males[b]	$\log_e$ weight = -10.86 + 2.829 $\log_e$ length	8	0.991
	Females[b]	$\log_e$ weight = -11.45 + 2.929 $\log_e$ length	11	0.990
Pipestone	Both[a]	$\log_e$ weight = -12.71 + 3.126 $\log_e$ length	126	0.974
	Both[b]	$\log_e$ weight = -13.21 + 3.216 $\log_e$ length	14	0.994
	Males[b]	$\log_e$ weight = -11.93 + 3.004 $\log_e$ length	8	0.997
	Females[b]	$\log_e$ weight = -13.29 + 3.229 $\log_e$ length	13	0.994
Walker	Both[a]	$\log_e$ weight = -10.70 + 2.807 $\log_e$ length	258	0.954
	Both[b]	$\log_e$ weight = -10.85 + 2.834 $\log_e$ length	13	0.997
	Males[b]	$\log_e$ weight = - 9.98 + 2.693 $\log_e$ length	9	0.997
	Females[b]	$\log_e$ weight = -10.88 + 2.839 $\log_e$ length	13	0.997

a calculated using individual lengths and weights from all sampled fish

b calculated using age-specific mean lengths and weights

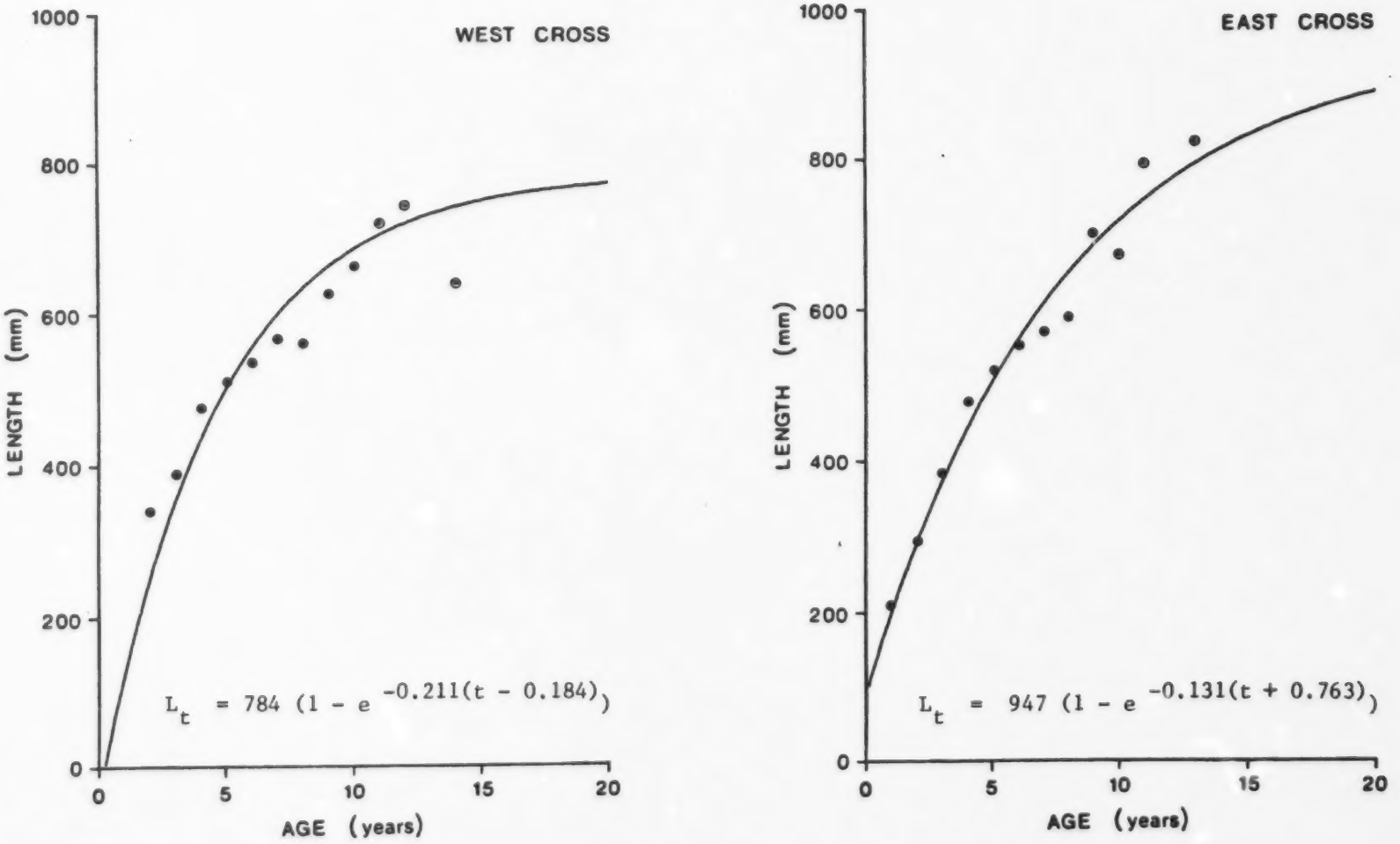
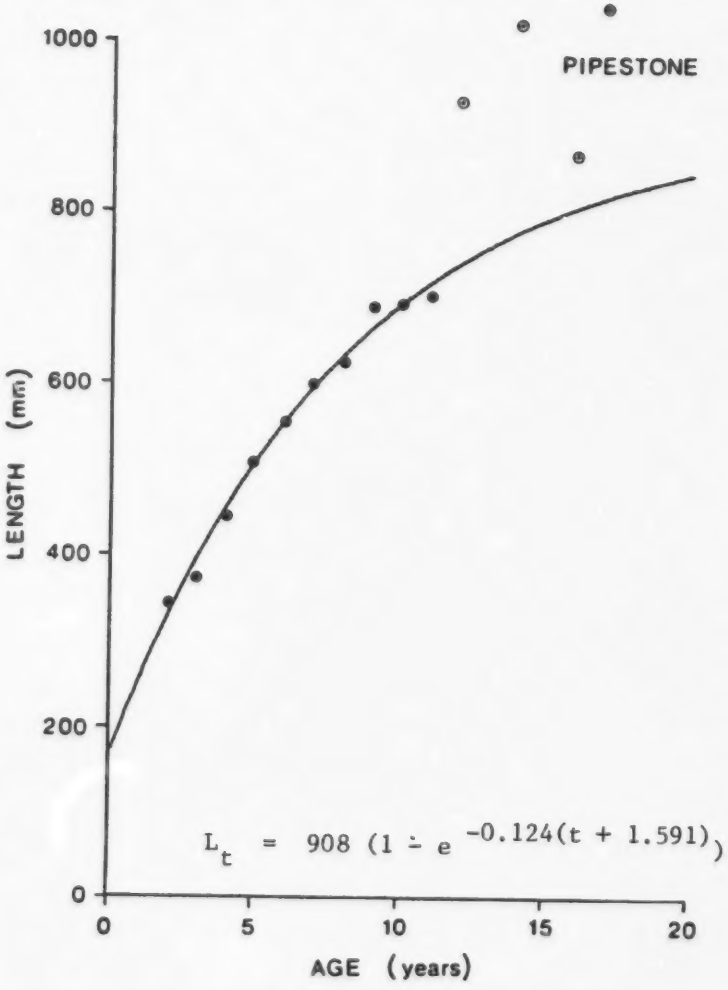


Fig. 16. Von Bertalanffy growth curves for pike from the west and east basin of Cross Lake, 1981.



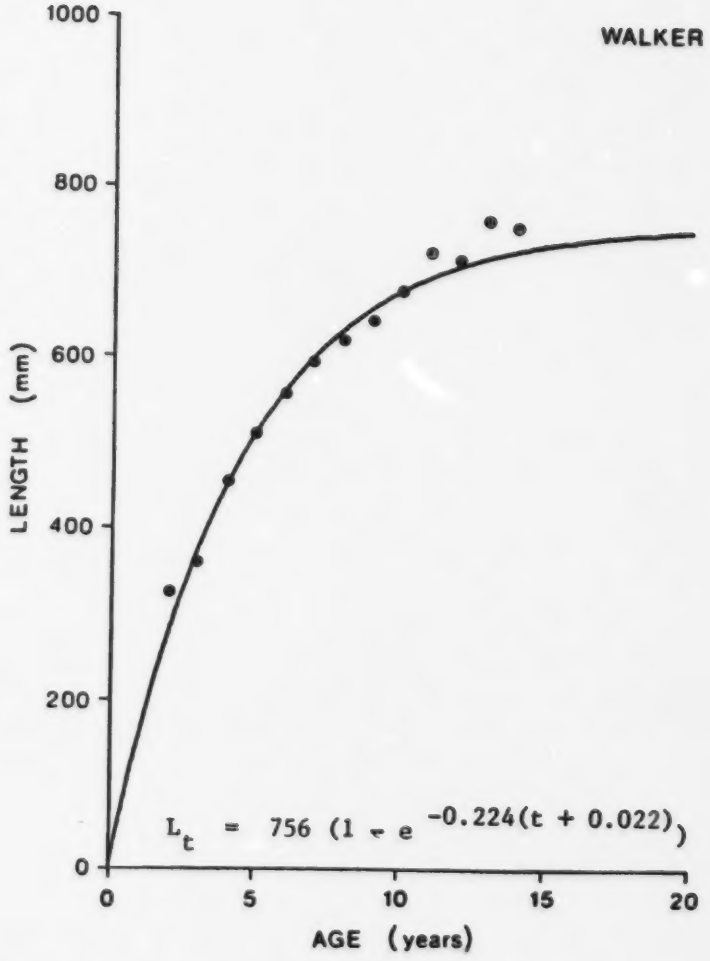


Fig. 17 . Von Bertalanffy growth curves for pike from Pipestone and Walker lakes, 1981.

Table 23. Coefficients used in von Bertalanffy model of pike growth, 1981.

Area	Walford Plot			Brody Plot			
	Ages used	Asymptotic length (mm)	r^2	Ages Used	Growth coefficient	t_o (years)	r^2
West Cross	2-10	784	0.909	2-12	0.211	+0.184	0.886
East Cross	1- 9	947	0.931	1-11	0.131	-0.763	0.923
Pipestone	2-11	908	0.972	2-11	0.124	-1.591	0.984
Walker	2-10,12	756	0.977	2-10,12	0.224	-0.022	0.986

Diet

Although unidentifiable fish remains were observed in many of the pike stomachs from Cross, Pipestone and Walker lakes, some fish species which occurred frequently were yellow perch, cisco and sticklebacks (Table 24). Invertebrates were also preyed on by pike, with primarily Decapoda (crayfish) occurring in Cross Lake, and Decapoda and Ephemeroptera (mayflies) in Pipestone and Walker lakes.

Cisco

Age Structure

Age structures of ciscoes were quite variable with Cross, Pipestone and Walker lakes having either bimodal or polymodal age distributions (Fig. 18, Appendices B52 - B56). Modes included age 2+ in Cross and Walker lakes, age 5+ in Whiskey Jack and Walker Lake, age 6+ in Pipestone Lake, and age 8+ in east Cross and Pipestone lakes. In the experimental samples mean age of males was either older than females, as in middle basin, east Cross, and Pipestone, or younger than females as in Whiskey Jack and Walker (Table 25).

Mortality

Whiskey Jack and Pipestone ciscoes had the lowest annual mortality rates at 0.307 and 0.310 respectively, with middle basin (0.446) and east Cross (0.475) having the highest (Table 26). Walker Lake had an intermediate mortality rate of 0.382.

Table 24 . Pike stomach contents, 1981. The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	West Cross	East Cross	Pipestone	Walker
Number examined	260	163	126	260
Number containing food	97	41	52	102
Fish	62.9(61)	78.0(32)	55.8(29)	68.6(70)
Whitefish	1.0(1)			1.0(1)
Cisco	5.2(5)			18.6(19)
White sucker	5.2(5)	2.4(1)	7.7(4)	2.9(3)
Walleye	1.0(1)	2.4(1)		1.0(1)
Sauger	1.0(1)			
Pike	1.0(1)	2.4(1)	3.8(2)	
Perch	9.3(9)	22.0(9)	9.6(5)	
Burbot			1.9(1)	2.0(2)
Trout-perch	3.1(3)		3.8(2)	
Shiners	5.2(5)	4.5(2)	5.8(3)	1.0(1)
Sticklebacks			13.5(7)	4.9(5)
Johnny darter			3.8(2)	1.0(1)
Sculpin				3.9(4)
Mooneye			1.9(1)	
Unidentified	32.0(31)	43.9(18)	15.4(8)	35.3(36)
Invertebrates	42.3(41)	22.0(9)	51.9(27)	43.1(44)
Hirudinea	4.1(4)		1.9(1)	1.0(1)
Amphipoda				2.9(3)
Decapoda	37.1(36)	19.5(8)	42.3(22)	16.7(17)
Ephemeroptera			13.5(7)	14.7(15)
Odonata		2.4(1)		
Chironomidae	1.0(1)			7.8(8)
Unidentified				2.0(2)

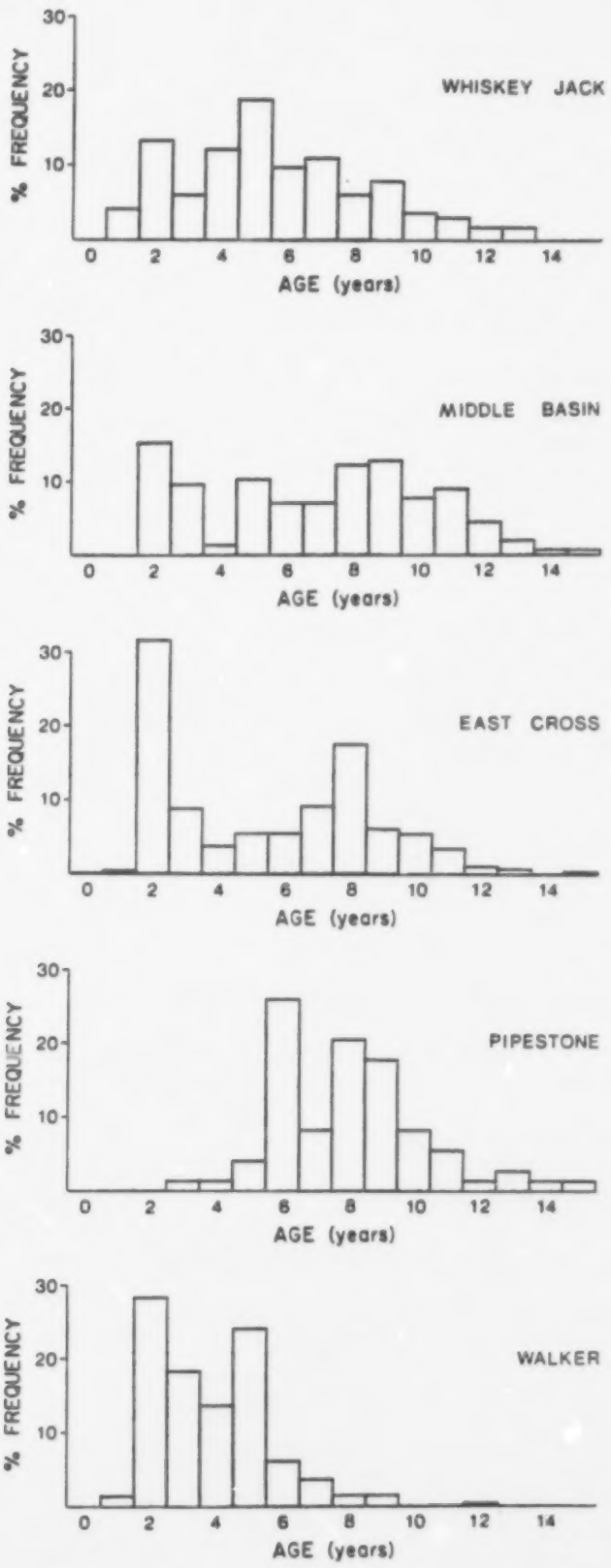


Fig. 18. Age-frequencies of cisco, 1981.

Table 25. Growth parameters and mean weighted age of onset of sexual maturity for cisco, 1981*.

Area	Sex	Mean age (years)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Mean age of maturity (years)
Whiskey Jack	Both	6.75	326	550	1.55	4.23
	Males	6.59	328	555	1.55	4.08
	Females	6.98	325	544	1.55	4.45
Middle Basin	Both	8.45	379	969	1.77	4.50
	Males	9.03	380	979	1.77	4.00
	Females	7.86	377	958	1.76	5.00
East Cross	Both	7.76	389	1145	1.93	3.36
	Males	7.85	384	1073	1.89	3.17
	Females	7.68	393	1204	1.97	3.58
Pipestone	Both	8.10	355	743	1.62	-
	Males	8.68	357	757	1.63	-
	Females	7.18	350	720	1.62	-
Walker	Both	5.24	265	283	1.51	3.18
	Males	5.23	265	288	1.52	3.10
	Females	5.25	265	280	1.50	3.27

* because of bimodal age distribution, ages 1+ - 3+ were not used in calculations of the means.

Table 26. Cisco mortality and survival rates estimated by Robson-Chapman and regression methods.

Method	Area	Ages Used	Instantaneous Mortality (Z)	Annual Mortality (A)	Annual Survival (S ± 2 S.E.)	r^2
Robson-Chapman	Whiskey Jack	6-13	0.366	0.307	0.693 ± 0.060	
	Middle Basin	10-15	0.590	0.446	0.554 ± 0.110	
	East Cross	9-13	0.645	0.475	0.525 ± 0.100	
	Pipestone	7-15	0.371	0.310	0.690 ± 0.074	
	Walker	3- 9	0.482	0.382	0.618 ± 0.044	
Regression	Whiskey Jack	6-13	0.280	0.244	0.756	0.911
	Middle Basin	10-15	0.605	0.454	0.546	0.915
	East Cross	9-13	0.607	0.455	0.545	0.923
	Pipestone	7-15	0.347	0.293	0.707	0.765
	Walker	3- 9	0.501	0.394	0.606	0.859

Covariance analyses indicated that ciscoes from Whiskey Jack had mortality rates which were significantly different (slopes) from the other study areas, with the exception of Pipestone Lake (Table 27). All other comparisons of mortality rate regressions between areas were non-significant at P = 0.05.

Growth

Length-weight regressions indicated negative allometric growth for Walker and Whiskey Jack ciscoes, positive allometric growth for the middle basin, and a combination of positive and negative allometric growths in east Cross and Pipestone lakes (Table28). Condition factors ranged between 1.50 and 1.97, with east Cross ciscoes having the highest condition followed by middle basin, Pipestone, Whiskey Jack and Walker (Table 25). Mean lengths and weights of the experimental catches also followed this hierarchy, with east Cross ciscoes being the longest and heaviest and Walker Lake ciscoes the shortest and lightest (Table 25).

Differences in growth of ciscoes (sexes combined) was most pronounced between Cross and Walker lakes (Figs. 19 and 20, Appendices B57 - B60). Asymptotic length of east Cross ciscoes (410 mm) was much longer than for Walker Lake ciscoes (289mm) (Table 29). Whiskey Jack and middle basin ciscoes had asymptotic lengths which were intermediate between east Cross and Walker lakes. Analysis of Pipestone Lake ciscoes was incomplete due to the small sample size. Covariance analyses indicated non-significant differences in growth between Whiskey Jack and middle basin ciscoes, and middle basin and east Cross ciscoes (Table 27). Significant differences in cisco growth were found in the other comparisons between Whiskey Jack, east Cross, middle basin and Walker Lake.

Table 27. Covariance analyses of mortality and growth curves for cisco (sexes combined), 1981.

Parameter	Comparison	Slopes		Elevations	
		F value (d.f.)	significance	F value (d.f.)	significance
Mortality rate (regression)	Whiskey Jack vs Middle	14.17(1,10)	*	2.49(1,11)	n.s.
	Whiskey Jack vs. East Cross	12.30(1, 9)	*	3.68(1,10)	*
	Whiskey Jack vs Pipestone	0.57(1,13)	n.s.	2.12(1,14)	n.s.
	Whiskey Jack vs Walker	6.11(1,11)	*	2.87(1,12)	n.s.
	Middle Basin vs East Cross	0.0001(1,7)	n.s.	2.00(1, 8)	n.s.
	Middle Basin vs Pipestone	3.53(1,11)	n.s.	5.98(1,12)	*
	Middle Basin vs Walker	0.60(1, 9)	n.s.	18.45(1,10)	*
	East Cross vs Pipestone	2.29(1,10)	n.s.	6.18(1,11)	*
	East Cross vs Walker	0.45(1, 8)	n.s.	18.52(1, 9)	*
	Pipestone vs Walker	1.62(1,12)	n.s.	0.93(1,13)	n.s.
Brody growth coefficient	Whiskey Jack vs Middle	1.25(1,18)	n.s.	1.74(1,19)	n.s.
	Whiskey Jack vs East Cross	2.73(1,18)	n.s.	7.31(1,19)	*
	Whiskey Jack vs Walker	13.55(1,15)	*	41.20(1,16)	*
	Middle vs East Cross	0.04(1,18)	n.s.	1.18(1,19)	n.s.
	Middle vs Walker	2.67(1,15)	n.s.	21.53(1,16)	*
	East Cross vs Walker	3.34(1,15)	n.s.	22.46(1,16)	*

* Significant at P = 0.05

Table 28 . Length-weight regressions for cisco, 1981.

Area	Sex	Length-weight equation	n	r^2
Whiskey Jack	Both[a]	$\log_e$ weight = -10.27 + 2.860 $\log_e$ length	164	0.987
	Both[b]	$\log_e$ weight = -10.17 + 2.846 $\log_e$ length	13	0.998
	Males[b]	$\log_e$ weight = - 9.97 + 2.812 $\log_e$ length	12	0.998
	Females[b]	$\log_e$ weight = -10.35 + 2.877 $\log_e$ length	13	0.998
Middle Basin	Both[a]	$\log_e$ weight = -12.51 + 3.264 $\log_e$ length	156	0.988
	Both[b]	$\log_e$ weight = -12.17 + 3.206 $\log_e$ length	14	0.996
	Males[b]	$\log_e$ weight = -12.41 + 3.245 $\log_e$ length	13	0.996
	Females[b]	$\log_e$ weight = -12.25 + 3.220 $\log_e$ length	13	0.995
East Cross	Both[a]	$\log_e$ weight = -12.04 + 3.198 $\log_e$ length	297	0.991
	Both[b]	$\log_e$ weight = -10.79 + 2.987 $\log_e$ length	14	0.995
	Males[b]	$\log_e$ weight = -11.00 + 3.017 $\log_e$ length	13	0.984
	Females[b]	$\log_e$ weight = -11.15 + 3.051 $\log_e$ length	12	0.998
Pipestone	Both[a]	$\log_e$ weight = -12.95 + 3.326 $\log_e$ length	73	0.868
	Both[b]	$\log_e$ weight = - 8.75 + 2.607 $\log_e$ length	13	0.737
	Males[b]	$\log_e$ weight = - 8.76 + 2.611 $\log_e$ length	12	0.773
	Females[b]	$\log_e$ weight = -13.29 + 3.381 $\log_e$ length	7	0.883
Walker	Both[a]	$\log_e$ weight = - 9.91 + 2.785 $\log_e$ length	278	0.965
	Both[b]	$\log_e$ weight = - 9.72 + 2.759 $\log_e$ length	10	0.985
	Males[b]	$\log_e$ weight = -10.52 + 2.905 $\log_e$ length	10	0.993
	Females[b]	$\log_e$ weight = -10.43 + 2.878 $\log_e$ length	8	0.982

a calculated using individual lengths and weights from all sampled fish

b calculated using age-specific mean lengths and weights

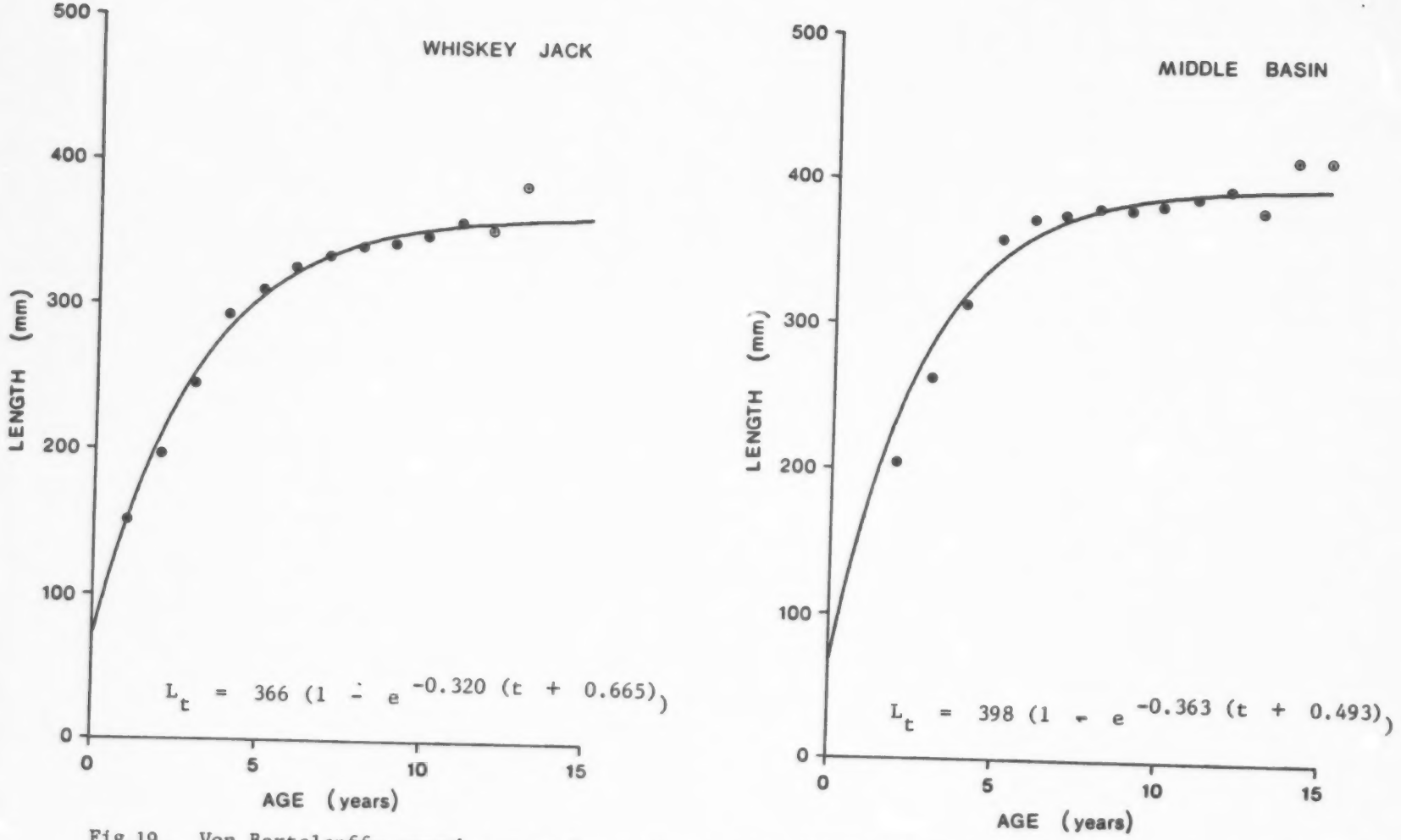


Fig.19. Von Bertalanffy growth curves for cisco from the Whiskey Jack and middle basins of Cross Lake, 1981.

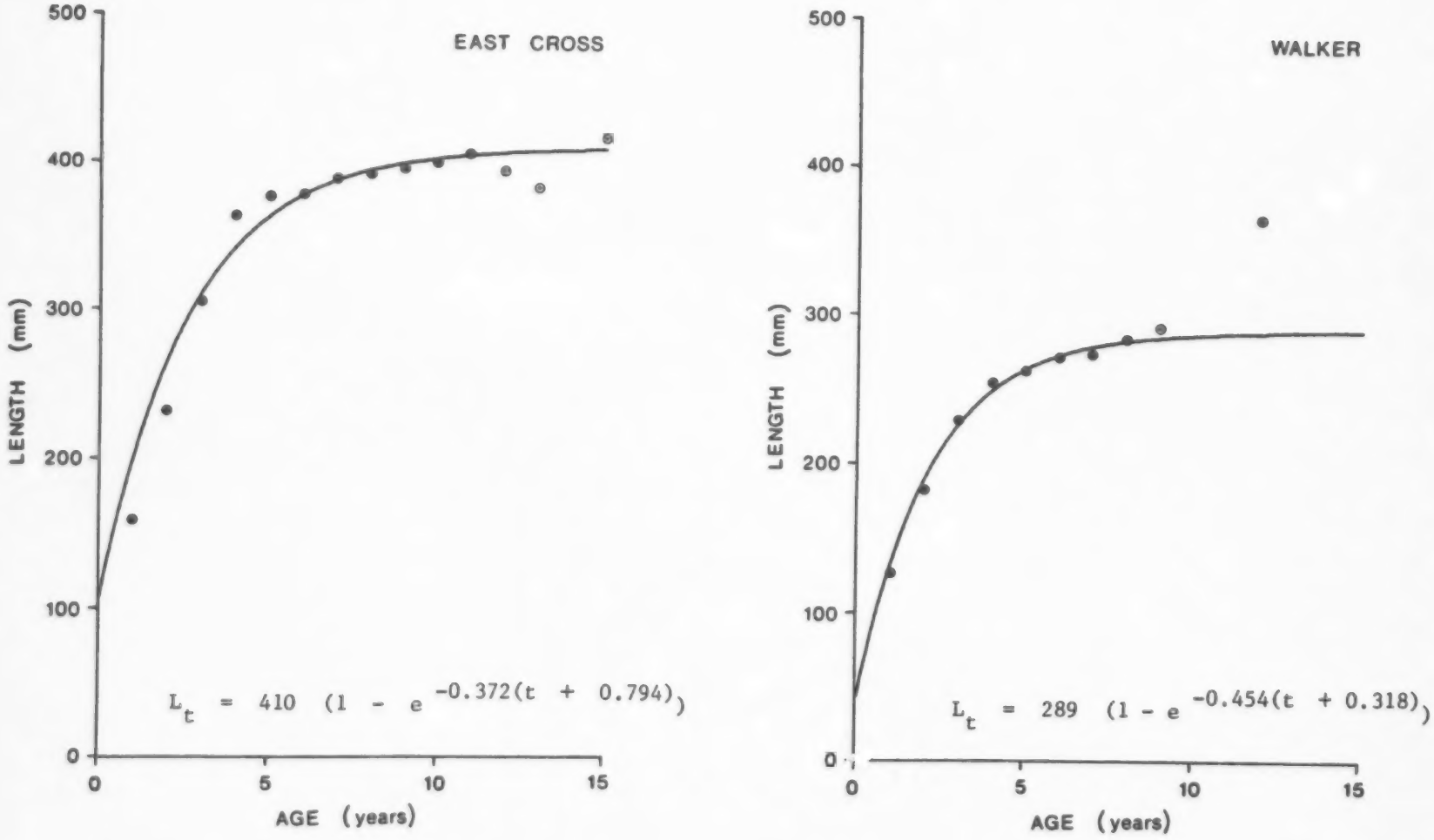


Fig. 20. Von Bertalanffy growth curves for cisco from east Cross and Walker lakes, 1981.

Table 29. Coefficients used in von Bertalanffy model of cisco growth, 1981.

Area	Ages used	Brody growth coefficient	Asymptotic length (mm)	t_o (years)	r^2 of Brody plot
Whiskey Jack	1-11	0.320	366	-0.665	0.971
Middle Basin	2-12	0.363	398	-0.493	0.927
East Cross	1-11	0.372	410	-0.793	0.959
Walker	1- 8	0.454	289	-0.318	0.971

Maturity

The mean weighted ages of onset of sexual maturity in cisco were similar between east Cross (3.36 years) and Walker (3.18 years) lakes (Table 25, Appendix B61). Ages at maturity in Whiskey Jack and middle basin were approximately one year older. In all areas examined, females were older than males at maturity.

Diet

The major food item found in cisco stomachs from Whiskey Jack, middle basin and Walker Lake was Cladocera (Table 30). East Cross ciscoes fed to a large extent on Amphipoda and Hemiptera, while Hemiptera and Ephemeroptera predominated in the stomachs of Pipestone Lake ciscoes.

Sauger

The few sauger captured in west Cross, Pipestone and Walker lakes precluded analyses of growth, mortality and maturity. However age distributions and age-specific mean lengths, weights and condition factors were compiled for the sauger from these three areas (Appendices B62 - B64).

Winterkill

At the end of March, 1981 fish kills were reported by residents of the Cross Lake community. It was observed that fish kills occurred in shallow bays and channels which were de-watered as a result of drawdown. The affected species, which were observed by fisheries personnel or Cross Lake residents, at three

Table 30. Cisco stomach contents, 1981. The percentage frequency of each food item is shown for only those stomachs containing food. Numbers in parentheses are the actual number of stomachs containing that food item.

	Whiskey Jack	Middle Basin	East Cross	Pipestone	Walker
Number examined	161	156	296	73	239
Number containing food	55	35	158	61	172
Gastropoda		17.1(6)	1.3(2)	34.4(21)	
Pelecypoda		17.1(6)	19.6(31)	23.0(14)	
Hydracarina		11.4(4)			2.3(4)
Cladocera	81.8(45)	22.9(8)	5.7(9)		77.9(134)
Amphipoda		11.4(4)	46.2(73)	9.8(6)	4.1(7)
Ephemeroptera	7.3(4)			54.1(33)	2.3(4)
Hemiptera	9.1(5)	8.6(3)	52.5(83)	73.8(45)	9.3(16)
Trichoptera			0.6(1)		
Chironomidae	5.5(3)	5.7(2)	27.8(44)	1.6(1)	8.7(15)
Chaoborus					4.7(8)
Plants		8.6(3)	0.6(1)		
Fish	1.8(1)				
Unidentified insects	1.8(1)	11.4(4)			9.9(17)

locations in Cross Lake, included white sucker, walleye and whitefish. Other species may have been killed but the ice cover prevented an accurate determination of the extensiveness of the fish kill.

Spawning Habitat Observations

Observations made in May, 1981 indicated that walleye were unable to move upstream through the Minago River crossing to a spawning area approximately 4 km upstream of Cross Lake. A total of 295 walleye and 182 pike, in spawning condition (ripe) were tagged downstream of the crossing with no recaptures obtained above the crossing. Water velocities through the crossing were measured by Manitoba Hydro on June 12, 1981 at 3.0 m sec^{-1} near the surface and 0.6 m sec^{-1} near the bottom (A. Cormie pers. comm.)

Concentrations of walleye were not observed at the Pickerel River (Fig. 1) in late May. B. Johanson (pers. comm.) confirmed the Pickerel River as a walleye and pike spawning area and observed no walleye or pike spawning in the river in 1980 or 1981. The Pickerel River rapids was very shallow and appeared, unsuitable for walleye spawning in 1981. Also, pike could not have spawned on the weedy shores since these areas were de-watered in May and June, 1981.

Historically, whitefish spawn in river channels on the west side of Cross Island (Fig. 1) between October 20 and November 30 (A. McIvor, J. McLeod, B. Johanson and others pers. comm.). It was observed that domestic fishermen were successfully netting whitefish, in spawning condition, from this area on October 20, 1981. It is believed that the whitefish spawned on submerged reefs, where suitable substrates of gravel and rock predominated.

Domestic Fishing Census

Annual harvest by domestic fishermen in Cross Lake was recorded at 103,116 kg (227,332 lbs.) which includes whitefish, walleye, pike, cisco and suckers (mostly white suckers) (Table 31). Considering only whitefish, walleye and pike the total harvest was 55,768 kg (122,947 lbs.).

Annual harvest figures may be underestimated by as much as 20% since the survey did not include fishermen who were unwilling to participate in the survey, and individuals who fished very infrequently. Active fishermen were identified through conversations with Cross Lake residents, J. McLeod, A. McIvor, C. Osborne and others.

The number of domestic fishermen in the survey decreased from a high level in the summer and fall of 1980 to a low level in the winter and spring of 1981 (Appendic C1). Over the one year period each fishermen set a minimum of 229 m (250 yds.) of net, with the maximum length of net set by one fishermen recorded at 25329 m (27,700 yds.) (Appendices C2 and C3). Fishermen preferred using 13.3 cm (5.25 in.) mesh, setting more than twice as many meters of 13.3 cm mesh as compared to 10.8 cm (4.25 in.) mesh. This was believed due to the fishermen's preference for whitefish. The highest c.u.e. (number) of whitefish was found for 13.3 cm mesh,while pike, walleye, cisco and suckers were caught more readily in 10.8 cm mesh (Figs. 21 and 22, Appendices C4 and C5). Peaks in c.u.e. occurred for whitefish and cisco during their spawning periods in late October and November. Also, for all species c.u.e. in both meshes peaked in mid-March.

Table 31 . Fish harvest by domestic fishermen in Cross Lake between August 4, 1980 and August 2, 1981.

Species	Mesh size (inches)							
	4.25			5.25			4.25 and 5.25 combined	
	Number caught	Mean weight* (kg)	Total weight (kg)	Number caught	Mean weight* (kg)	Total weight (kg)	Number caught	Total weight (kg)
Whitefish[1]	2430	1.713	4163	10639	1.910	20320	13069	24483
Walleye[2]	7908	1.000	7908	8294	0.970	8045	16202	15953
Pike[3]	1906	2.326	4433	3621	3.010	10899	5527	15332
Cisco[4]	8481	0.808	6853	14336	0.927	13289	22817	20142
Suckers[5]	6840	1.292	8837	11346	1.619	18369	18186	27206
Total 1,2&3	12244	-	16504	22554	-	39264	35798	55768
Total 1-5	27565	-	32194	48236	-	70922	75801	103116

* mean weights for whitefish, walleye and pike are calculated from combined 1980 and 1981 catches in experimental nets in the west basin of Cross Lake. Cisco mean weights are based on 1981 experimental catches in west Cross Lake, while sucker weights are from 1981 experimental catches in Pipestone and west Cross lakes.

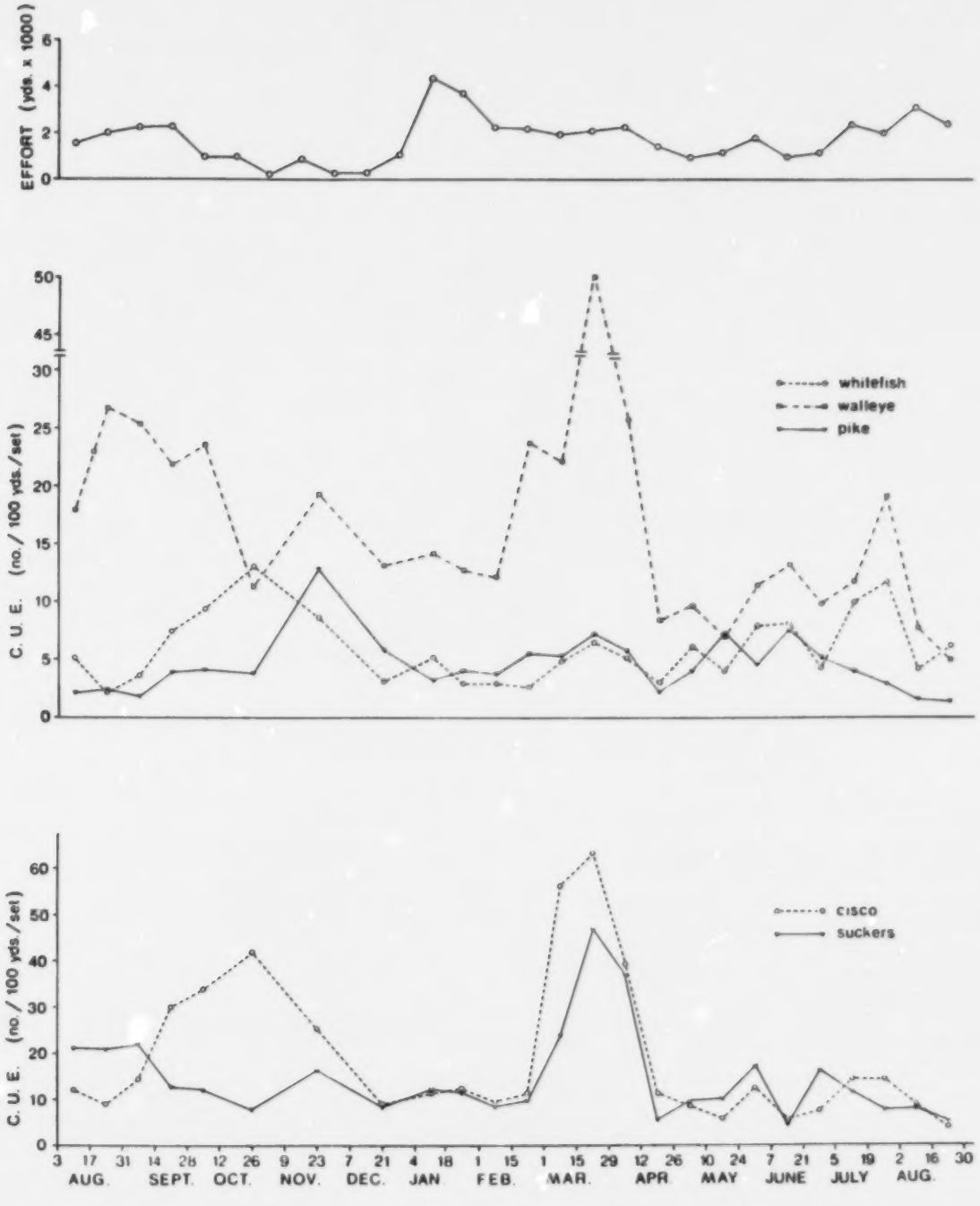


Fig. 21. Temporal changes in fishing effort and in catch per unit effort for fish caught in 4.25 inch nets by the domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 30, 1981. Between Oct 13 and Jan. 4, c.u.e. statistics were averages of four week periods.

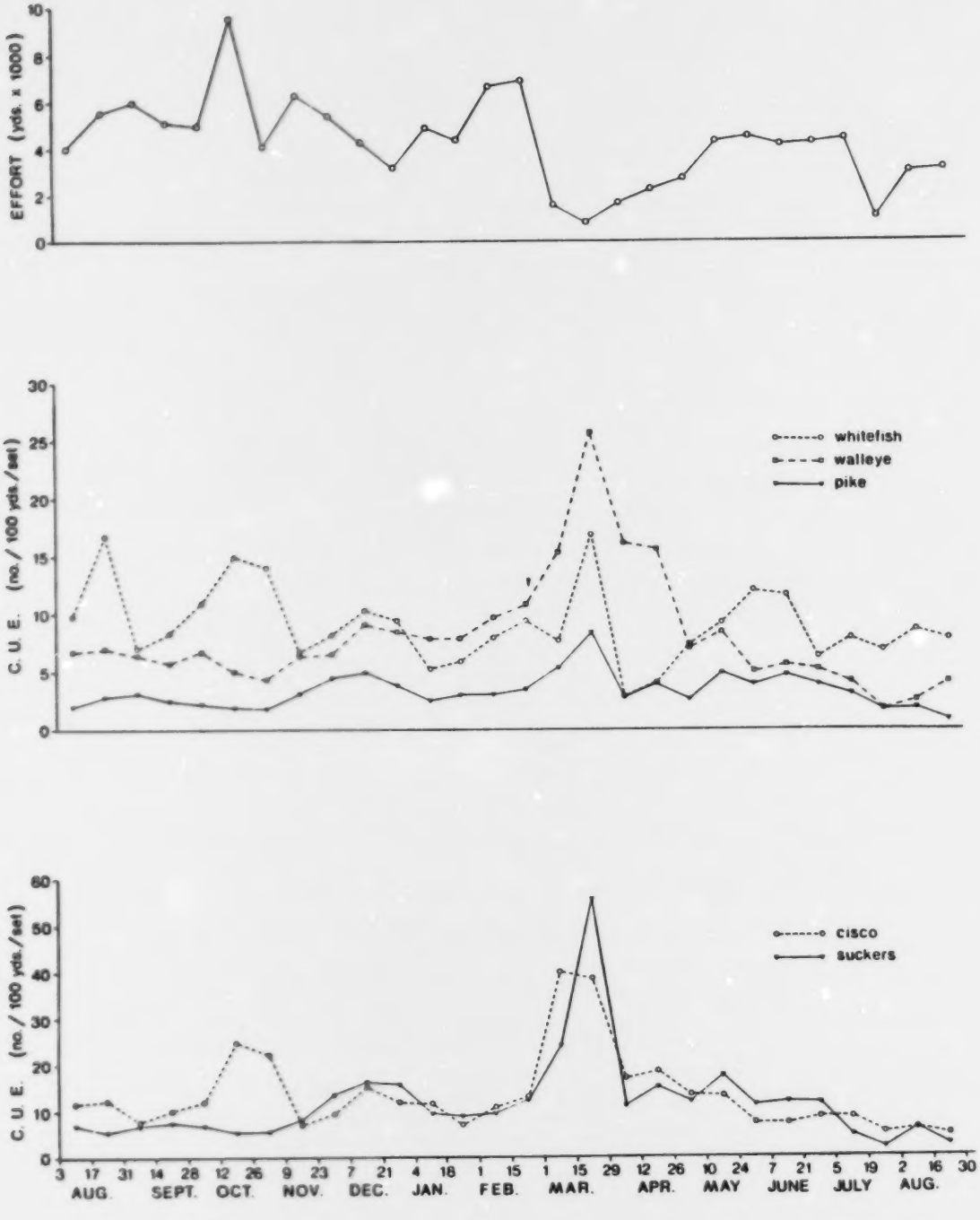

EFFORT (yds. x 1000)
C. U. E. (no./ 100 yds./set)
whitefish
walleye
pike
C. U. E. (no./ 100 yds./set)
cisco
suckers
3 17 31 14 28 12 26 9 23 7 21 4 18 1 15 1 15 29 12 26 10 24 7 21 5 19 2 16 30
AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY AUG.

Fig. 22 . Temporal changes in fishing effort and in catch per unit effort for fish caught in 5.25 inch nets by the domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 30, 1981.

DISCUSSION

Limnology

Changes in the limnology of Cross and Pipestone lakes since regulation could not be quantified because of inadequate pre-regulation data. Water chemistry at the outlet of Cross Lake was monitored, however, in 1973 (Cleugh 1974), but no significant changes in chemical composition have occurred since regulation. Physico-chemical water quality measurements varied insignificantly between the 1980 (Gaboury and Patalas 1981) and 1981 studies. In comparison to 1980, mean plankton biomass in 1981 was lower in the east and middle basins, but higher in Sagatawak, Jenpeg, Whiskey Jack and Pipestone Lake. The wide variability in the plankton dry weights at each station over the summers resulted in non-significant differences between 1980 and 1981 mean plankton biomasses. The trend of decreasing plankton biomass from east to west basins was evident in both years.

The predominant benthos in Cross and Pipestone lakes were Amphipoda, Chironomidae, Gastropoda and Pelecypoda in 1980 and 1981. Ephemeroptera were also abundant in west Cross and Pipestone lakes. Driver and Doan (1972) also found that these invertebrate orders predominated in 1965. Although food did not appear to be limiting present fish stocks in Cross and Pipestone lakes, it is believed that under drawdown the standing crops of plankton and benthos were lower because of the decrease in lake volume and exposure of littoral zone (Bennett 1962, Cowell and Hudson 1968, Hale and Bayne 1980).

Fisheries

Insufficient fishing efforts were made in 1965 (Driver and Doan 1972) and 1973 (Ayles *et al.* 1974) for confident comparisons, of ages distributions, growth rates, and relative and absolute fish abundances, with 1980 and 1981 data. In the 1980 and 1981 studies it was evident that more intensive exploitation (commercial) in east Cross Lake has resulted in fewer older whitefish and pike being caught in comparison to west Cross Lake. Walleye populations in Cross, Pipestone, and Walker lakes had similar age distributions, implying similar rates of exploitation. Growth rates of whitefish, walleye, pike and cisco were significantly different between the east and west basins of Cross Lake, as fish either attained similar asymptotic lengths but had different Brody growth coefficients, or attained different asymptotic lengths and had similar Brody growth coefficients (Table 32). Differences in growth rates and age distributions indicated that east Cross and west Cross had discrete fish populations.

Except for Walker Lake walleye, mean ages at maturity (Abrasov's method) of each species (sexes combined) were similar between and within the study areas in both years (Table 32). Wide variability in the annual survival rates was due to the occurrence of weak and strong year classes beyond the modal ages. The annual survival rates of each species were not significantly different between study areas because the rates overlapped when plus or minus two standard errors (i.e. 95% confidence interval) were considered.

Table 32. Summary of von Bertalanffy growth parameters, mean ages of maturity and annual survival rates of Cross Lake fish (sexes combined) in 1980 and 1981.

Species	Area	Year	Growth				Mean Age of Maturity (yrs)	Annual Survival Rate (S + 2 S.E.)
			N	K	L_∞	t_o		
Whitefish	West Cross	1980	221	0.239	530	-0.232	5.50	0.567 ± 0.127
		1981	140	0.256	523	-0.451	5.93	0.731 ± 0.055
	East Cross	1980	204	0.304	529	0.312	5.30	0.526 ± 0.164
		1981	155	0.305	531	-0.473	6.06	0.720 ± 0.078
	Walker	1981	121	0.190	538	-1.648	5.33	0.659 ± 0.072
Walleye	West Cross	1980	346	0.217	477	-0.265	7.65	0.723 ± 0.105
		1981	275	0.227	464	-0.439	7.63	0.574 ± 0.057
	East Cross	1980	586	0.222	462	-0.838	7.38	0.651 ± 0.166
		1981	320	0.186	466	-1.201	7.48	0.697 ± 0.038
	Pipestone	1980	144	0.294	439	+0.179	7.68	0.717 ± 0.063
		1981	229	0.232	454	-0.557	8.84	0.701 ± 0.048
	Walker	1981	113	0.178	527	-0.156	9.03	0.660 ± 0.068
Pike	West Cross	1980	213	0.147	945	+0.057	3.95	0.600 ± 0.092
		1981	261	0.211	784	+0.184	4.05	0.490 ± 0.082
	East Cross	1980	285	0.144	897	-1.128	3.07	0.465 ± 0.108
		1981	163	0.131	947	-0.763	3.49	0.476 ± 0.078
	Pipestone	1980	98	0.120	960	-0.580	4.61	0.541 ± 0.095
		1981	126	0.124	908	-1.591	-	0.568 ± 0.111
	Walker	1981	258	0.224	756	-0.022	4.36	0.491 ± 0.079
Cisco	East Cross	1980	239	0.392	404	-0.436	2.90	0.444 ± 0.051
		1981	294	0.372	410	-0.793	3.36	0.525 ± 0.100

With increased fishing effort in 1981, total c.u.e. of whitefish, walleye and pike declined from 1980 levels with the most dramatic decrease occurring in east Cross Lake (Table 33). Pipestone Lake had the lowest catches, with Walker Lake catches being intermediate between Cross and Pipestone lakes. In general the relative abundances of each species varied between east Cross, west Cross and Pipestone lakes in each year, and within the same basin in different years (Fig. 23). However, in both basins of Cross Lake in 1980 and 1981, cisco remained most abundant averaging 43% of the total catch, followed by walleye (24%), pike (9%) and whitefish (6%). Walleye were most abundant in Pipestone Lake, with whitefish averaging 4.5 % of the total catch in both years.

Declines in c.u.e. from 1980 to 1981 indicated decreases in the absolute abundances of fish. C.U.E. for whitefish, walleye, pike and cisco decreased in all areas except Whiskey Jack and Jenpeg basins (Fig. 23). In the Jenpeg basin, whitefish, walleye and pike increased, while in Whiskey Jack only walleye increased. Whitefish and cisco showed the greatest declines, with c.u.e. in west and east Cross and Pipestone lakes about 50% lower in 1981. Comparing post-regulation catches at similar summer drawdown levels, c.u.e. of whitefish in 13.3 cm mesh declined from 35 fish/91 m/night in 1977 (B. Wright unpubl. data) to 9 in 1980 and 4 in 1981 (Fig. 24).

Table 33. Fishing effort and catches/standard gang/16 h of whitefish, walleye and pike.

Area	Year	Number of Sets	C.U.E.	
			Number	Biomass (kg)
West Cross	1980	22	40.36	43.03
	1981	28	37.07	34.45
East Cross	1980	17	79.47	69.69
	1981	25	48.20	40.15
Pipestone	1980	17	17.18	16.32
	1981	28	13.96	13.82
Walker	1981	25	26.20	38.05

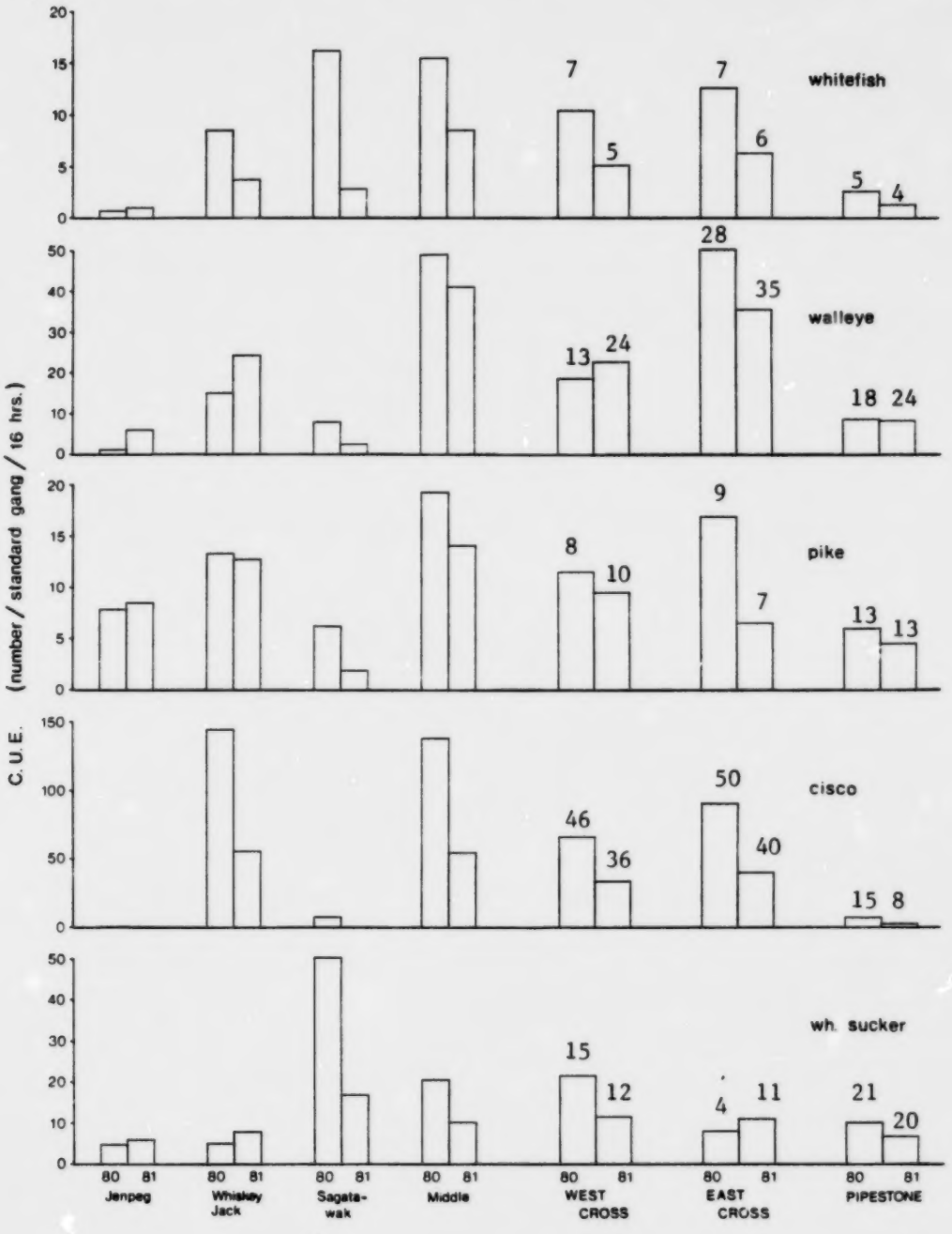


Fig. 23 . Comparison of catch per unit of effort and relative abundance (in % above bars) for fish captured in Cross and Pipestone lakes in 1980 and 1981. Jenpeg, Whiskey Jack, Sagatawak and Middle are basins within west Cross Lake.

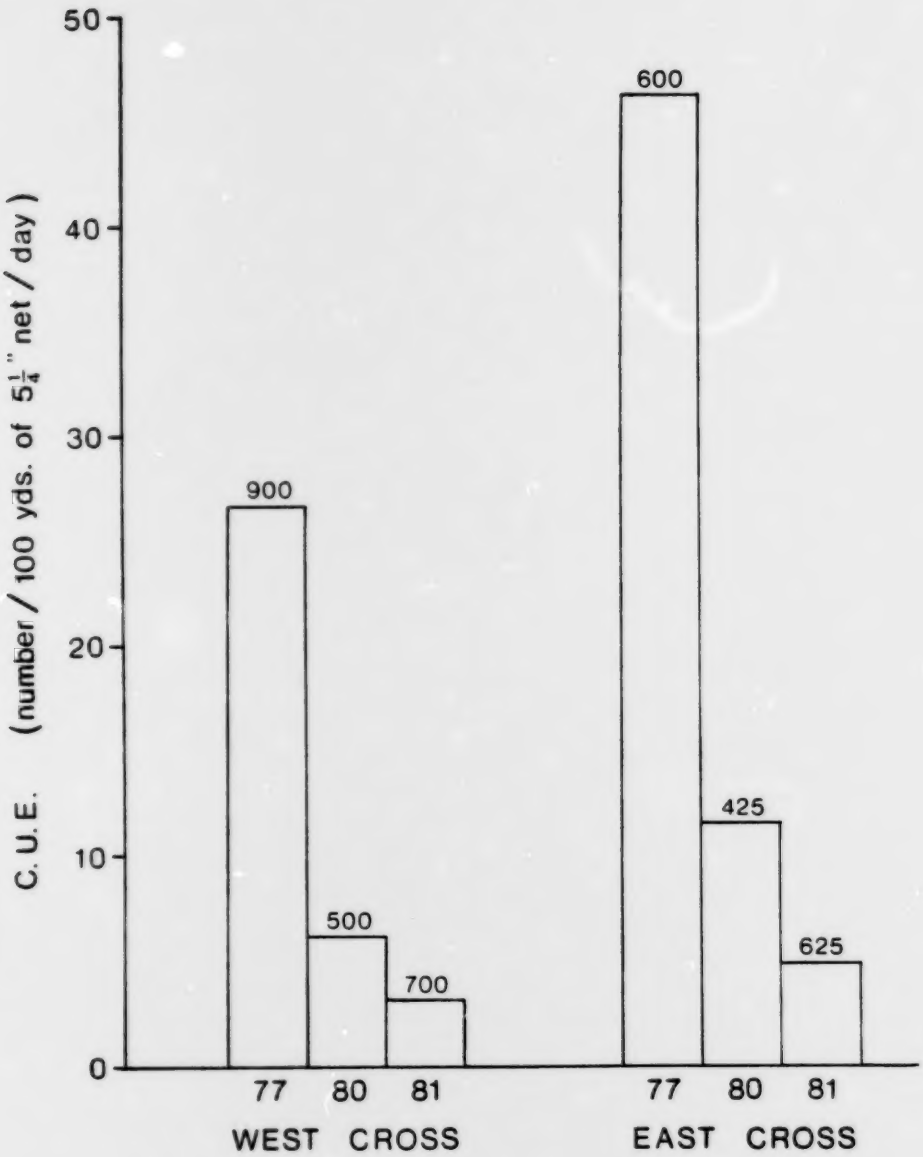


Fig. 24 . Catch per unit effort for whitefish caught in 5.25 inch nets in 1977, 1980 and 1981. Numbers above the bars represent effort (yds. of net).

Effects of Drawdown on Fish Reproduction and Natural Mortality

The current water level regime on Cross and Pipestone lakes has resulted in as much as a 53% decrease in natural lake volumes during summer drawdown, and dramatic decreases in water levels from fall to spring. The effects of a decrease in summer lake volume were discussed by Gaboury and Patalas (1981), and included:

1. a reduction in the available habitat for fish and plankton
2. a de-stabilization of the littoral zone and a reduction of habitat area for benthos and,
3. a decrease in mean water depth resulting in high summer water temperatures, a proliferation of submergent vegetation, and increased turbidity in the east basin of Cross Lake through resuspension of bottom sediments.

Dramatic decreases in water levels from fall to spring has detrimentally affected the reproductive success of whitefish, cisco, walleye and pike, and caused a fish winterkill in 1981.

Increased winter drawdown under the regulation of Cross Lake has had a pronounced effect on the year class strengths of coregonid fishes. There have been rapid decreases in water levels in late spring in four of the last five years since regulation (Fig. 25), and fall to spring drawdowns of up to 2.2 m have occurred, as compared to natural variations of < 1.4 m (Appendix B65). An

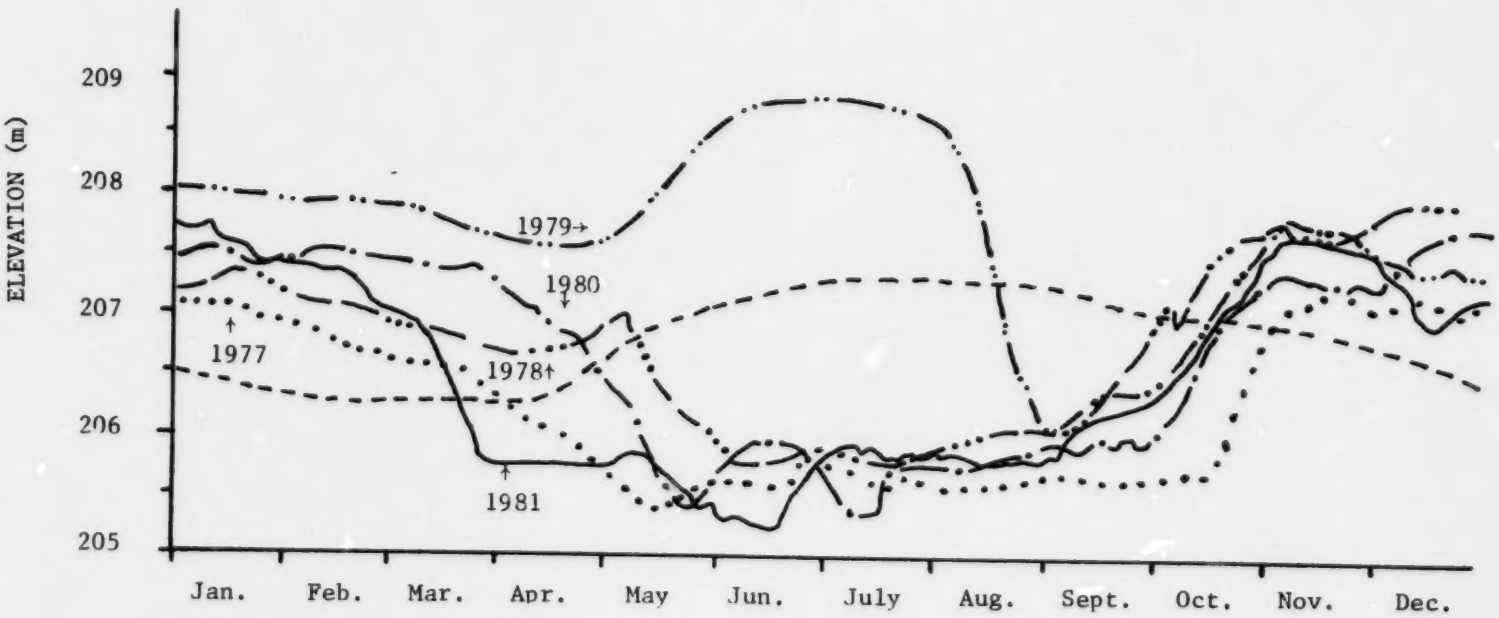


Fig. 25. Comparison of the average monthly water levels on Cross Lake under unregulated conditions (1928 - 1966) (---) and the levels recorded under regulation (1977 - 1981). Data provided by the Manitoba Water Resources Branch.

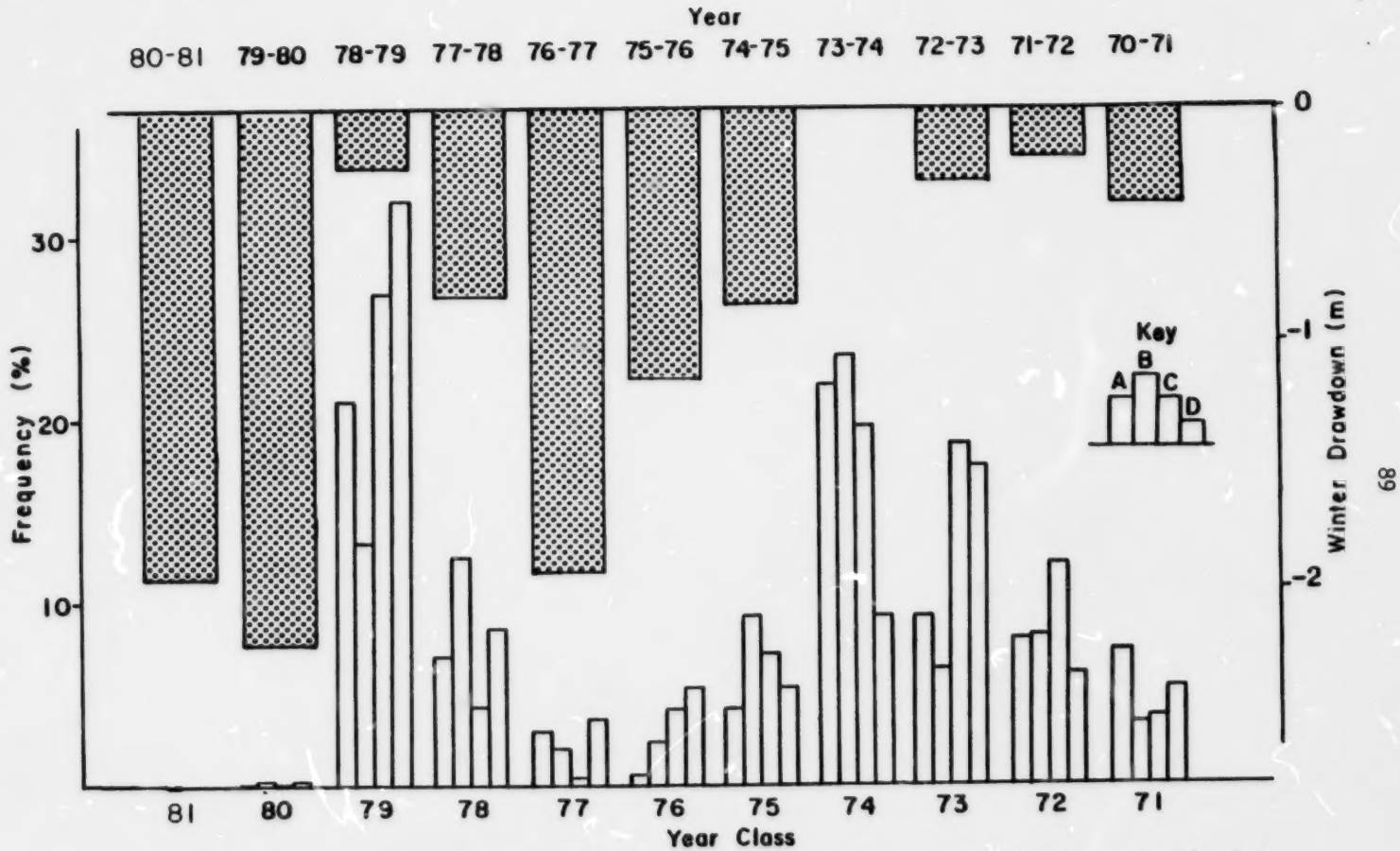


Fig.26. Relationship between winter and spring drawdown in Cross Lake and whitefish and cisco year class success, 1971-1981. Winter and spring drawdown calculated as minimum level between October 28 and May 31 subtracted from level on October 28. A. Percent frequency of whitefish in 1980 gillnet catches. B. Percent frequency of whitefish in 1981 gillnet catches. C. Percent frequency of cisco in 1980 gillnet catches. D. Percent frequency of cisco in 1981 gillnet catches.

inverse relationship was found between the strengths of whitefish and cisco year classes produced in 1971 - 1980 and the difference between water levels at spawning time (October 28) and lowest water level until the end of May (Fig. 26) (Gaboury and Patalas 1981). This relationship was also apparent from the 1981 experimental coregonid age-frequencies. Weak year classes of whitefish and cisco resulted from years with a marked winter drawdown and strong year classes tended to result from years with little winter drawdown. It is believed that drawdown has detrimentally affected whitefish and cisco hatching success and recruitment by a de-watering of spawning areas and desiccation of eggs.

Even though sample sizes of Pipestone Lake whitefish were small in 1980 (Gaboury and Patalas 1981) and 1981, the negative impact of drawdown on year class strengths was also evident from the age-frequencies. Regulation of Cross Lake did not appear to affect coregonid reproductive success in Walker Lake, since water levels in Walker Lake are regulated, to a large extent, by a shallow rapids at its outlet.

Based on age-frequencies, Whiskey Jack ciscoes appeared to be less affected by winter drawdown than middle or east basin ciscoes. Growth analyses suggested that Whiskey Jack ciscoes were a discrete population. The steep, rock shorelines in Whiskey Jack dampens the changes in lake area with drawdown, thereby reducing egg mortality from winter drawdown.

The low frequencies of the 1975 to 1978 year classes (Fig. 26) cannot be explained by gill net selectivity. A standard gang of gill nets tends to underestimate the relative frequencies of smaller fish, but as fish size increases, efficiency at capturing a greater proportion of the fish in successively larger size groups increases (Hamley 1975). Accordingly the 1975 to 1978 year classes should be better represented than the 1979 year class.

Although the effect of drawdown on coregonid year class strengths has not, to our knowledge, been previously documented for lakes below hydro electric developments, this inverse relationship has been found for whitefish inhabiting reservoirs (Ioganzen and Podlesnyi 1958 and Sminov 1964, cited in Machniak 1975) and for spring spawners when drawdown occurs just prior to spawning (Benson 1973, Jester 1971). June (1970) found that large numbers of atretic eggs in the ovaries of pike were associated with drawdown prior to spawning. Spawning of Cross and Pipestone lakes walleye and pike were also detrimentally affected by drawdown. Walleye were observed congregating below known spawning tributaries (Minago and Pickerel rivers) made inaccessible by low water levels, and known spawning areas for pike (Pickerel River) were de-watered prior to spawning. Poor representation in the Cross Lake experimental net catches of walleye and pike younger than the 1976 year class precluded a comparison between drawdown and year class strengths. There were indications however, from the 1981 Pipestone Lake walleye age-frequencies of an inverse relationship between drawdown and year class strengths.

Drawdown (1.4 m) of Cross Lake in March, 1981 (Fig. 25) de-watered shallow bays and channels, and resulted in the stranding and suffocation of fish. At this time dissolved oxygen concentrations were already low (< 3 mg l^{-1}) in basins removed from the effects of river flows (Gaboury and Patalas 1981). Low oxygen levels were believed caused by the decay of extensive areas of submergent vegetation which proliferated with the shallow water depths in the summer of 1980. Also, during this period c.u.e. of all fish species captured by domestic fishermen in Cross Lake increased dramatically. Increased fish movements were believed due to the loss in available habitat, and to stress caused by low oxygen levels in shallow areas.

Drawdown and low oxygen levels contributed to the increase in winter mortality, and together with high summer water temperatures and the detrimental effects of drawdown on fish reproduction has resulted in a decrease in the absolute abundances of Cross and Pipestone lakes fish from 1980 to 1981. C.U.E. decreased more in east Cross than in west Cross or Pipestone lakes because of the greater reduction in area and volume in the east basin with drawdown. Also west Cross and Pipestone lakes had generally higher winter dissolved oxygen concentrations due to the influence of the Nelson River.

Commercial Quotas

As suggested by Gaboury and Patalas (1981), commercial fish quotas in Cross and Pipestone lakes should be based on historic

commercial fish yields, at lake volumes during unregulated years, correlated to minimum summer lake volumes under regulated conditions. This assumes, however, that fish recruitment and survival rates are similar under unregulated and regulated conditions. Clearly this assumption has not been met. With a minimum east Cross Lake volume at 29% of its historic volume, it is recommended that the commercial quota be reduced to approximately 13,608 kg (30,000 lb.) of whitefish, walleye and pike. The commercial quota of Pipestone Lake should be decreased to 6800 kg (15,000 lb.) of whitefish and walleye to coincide with the 47% decrease in lake volume. The mesh size restriction in both lakes should remain at 13.3 cm (5.25 in.). Exploitation now of the depressed whitefish stocks using a mesh size smaller than 13.3 cm (5.25 in.) could endanger a recovery of the stocks if, in the future, the proposed water level regime was adopted. Review of the commercial quota and mesh size restrictions will be made if the minimum Cross Lake stage increases. Adjustments in the commercial fishing regulations will be based on the analyses of future commercial and experimental fish samples.

Proposed Water Level Regime

Prior to regulation (1918 - 1933, 1950 - 1973), the differences between water levels at coregonid spawning time (October 28)

and the lowest water level until May 31 were < 1.40 m (Appendix B65, Fig. 27). Minimum post-spawning water levels ranged from 205.50 to 207.49 m, and averaged 206.48 m. The deleterious effects of drawdown on coregonid year class strengths may have been inherently dampened under unregulated conditions. In years when post-spawning drawdown was > 1 m, minimum water levels were > 205.75 m. Also, in years when minimum post-spawning water levels were < 205.75 m, the differences between spawning and post-spawning water levels were < 0.70 m. In contrast, post-spawning stages have been as low as 205.3 m in 1977, 1980 and 1981, with water level drawdowns $\geq$ 1.90 m in the three years.

It is impossible to conclude that minimum post-spawning stages <206.0 m before regulation were adequate levels for successful coregonid hatching without fish production records from the 1920's and 1930's. It is suspected that relatively weak year classes of coregonids were produced when post-spawning levels were < 206.0 m. Since minimum stages between 206.2 and 206.5 m, with an average drawdown < 1.0 m, occurred frequently before regulation, it is believed that these conditions were adequate for successful coregonid hatching.

Adequate May and June water levels are critical for successful walleye and pike spawning, egg incubation and hatching. Prior to regulation, minimum mean monthly water levels were recorded at 206.2 m in May and 206.3 m in June, but the majority of water levels were greater than 206.8 m (Table 34). Under regulation mean monthly water levels in May and June have been between 205.3 and 205.9 m in 1977, 1978, 1980 and 1981 (Manitoba Water Resources Branch).

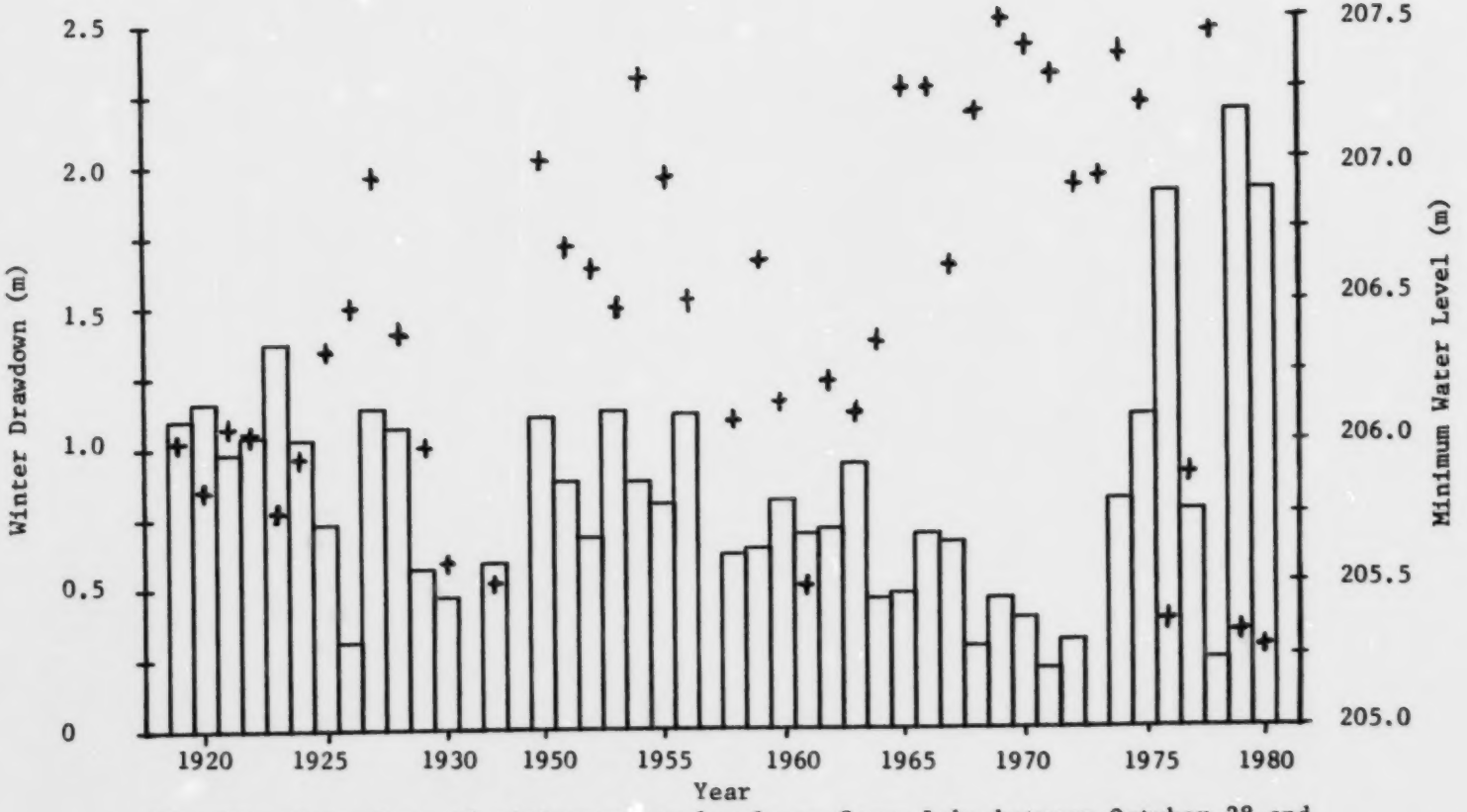


Fig. 27. Comparison of minimum water levels on Cross Lake between October 28 and May 31 (+), and winter/spring drawdown (bars). Winter and spring drawdown calculated as minimum level between October 28 and May 31 subtracted from level on October 28. See Appendix B65 for a more detailed description of data used.

Table 34. Percent frequency of occurrence of mean monthly Cross Lake stages prior to regulation, 1918 - 1973. Data provided by Manitoba Water Resources Branch.

Month	Cross Lake Stage (m)							
	Mean	Minimum	<206.00	206.00-206.29	206.30-206.49	206.50-206.79	>206.79	Maximum
May	207.04	206.23	0	7(2)	7(2)	15(4)	70(19)	208.04
June	207.37	206.30	0	0	4(1)	11(3)	88(29)	208.60

A minimum stage of 206.5 m for the Cross Lake outlet control structure, with a maximum drawdown of approximately 1.5 m would ensure, based on pre-regulation water levels, coregonid hatching success. Also, 206.5 m would probably be the minimum water level for successful walleye and pike reproduction. Prior to construction of the control structure it is proposed that:

1. water levels during coregonid spawning in October and November be between 206.9 and 207.5 m,
2. drawdown after October 28 and before May 31 be $\leq$ 1.0 m below the October 28 level,
3. the minimum water level from October 28 to May 31 be > 206.0 m and preferably at 206.5 m, and
4. the minimum water levels during May and June be 206.5 m.

A minimum May-June level of 206.5 m would reduce water velocities through the Minago River crossing below the rates recorded in 1981, but the velocities may still impede upstream spawning migrations of walleye. This would require further monitoring of water velocities and walleye movements during the spring.

SUMMARY AND CONCLUSIONS

In the 1980 (Gaboury and Patalas 1981) and 1981 studies, it was found that:

1. At a minimum discharge of ∿ 20 m^3 sec^{-1} from Jenpeg, summer volumes of Cross and Pipestone lakes were 53% smaller than their average unregulated volumes,
2. The east and west basins of Cross Lake were comprised of discrete populations of whitefish, walleye, pike and cisco, with species having different growth rates, age distributions, and in some cases, ages at maturity in each area,
3. Catch per unit of effort of all fish species in Cross and Pipestone lakes decreased from 1980 to 1981, while relative abundances were similar between years, with the exception of walleye and pike,
4. Spring water levels in Cross and Pipestone lakes have been between 1.9 and 2.2 m lower than the previous fall level in three of the last seven years of regulation ,
5. Water level drawdown has had a negative impact on coregonid year class strength, apparently through a de-watering of their spawning areas and desiccation of the eggs ,
6. Early spring (March) drawdown resulted in a de-watering of shallow bays and channels, and the stranding and suffocation of fish,

7. Low spring (May, June) water levels have made spawning areas in the Minago and Pickerel rivers inaccessible to walleye and pike,
8. Low summer water levels in Cross and Pipestone lakes have resulted in mean depths < 1.6 m, high bottom water temperatures (20 - 22C), and a proliferation of submergent vegetation. The decay of extensive areas of submergent vegetation resulted in low dissolved oxygen levels (0.9 - 2.4 mg l^{-1}) during the winter,
9. Walker Lake morphometry was not affected significantly by Jenpeg regulation. Based on age distributions, growth and maturity, fish populations appear to be healthy , and
10. Cross Lake domestic fishermen harvested an estimated 40,500 kg of whitefish and walleye between August 4, 1980 and August 2, 1981.

RECOMMENDATIONS

It is recommended that:

1. the commercial quota of east Cross Lake be reduced to 13,608 kg (30,000 lb.) of whitefish, walleye, and pike, and the mesh restriction remain at 13.3 cm (5.25 in.),
2. the commercial quota of Pipestone Lake be reduced to 6800 kg (15,000 lb.) of whitefish, and walleye, and the mesh restriction remain at 13.3 cm (5.25 in.),
3. the minimum water level for the Cross Lake outlet control structure be set at 206.5 m,
4. in the absence of an outlet control structure, water levels should be regulated above a minimum of 206.0 m between October 28 and May 31, and at 206.5 m during May and June. Also drawdown after October 28 and before May 31 should be $\leq$ 1.0 m below the October 28 level, and
5. future studies on Cross Lake include:
    i. a stock assessment of the east Cross Lake fish in four years to further assess the effects of a regulated water level regime, through comparisons with 1980 and 1981 data, and
    ii. monitoring of water velocities at the Minago River crossing to determine an acceptable minimum Cross Lake stage to satisfy fish passage criteria (Whitehead 1978). These investigations should be

conducted by Manitoba Hydro and would involve water velocity measurements on at least two occasions in early May. Monitoring should begin in 1982 and continue each spring until a suitable Cross Lake stage has been determined or it is concluded that the crossing is inadequate and the structure is either modified or replaced. Then Fisheries Branch could conduct a walleye tagging study to verify that the structure and minimum water level are acceptable for upstream fish passage in the spring.

LITERATURE CITED

Abrasov, V. N. 1967. Determination of commercial turnover in natural bodies of water. Problems of Ichthyology. Trans. from Russian by Am. Fish Soc. 9: 482 - 489.

Anthony, L. 1963. Summer activity report - 1963: biological surveys north. Man. Dept. Mines and Nat. Res. 5p.

Ayles, H., S. Brown, K. Machniak and J. Sigurdson. 1974. The fisheries of the lower Churchill lakes, the Rat-Burntwood lakes, and the upper Nelson lakes: present conditions and the implications of hydroelectric development. Lake Winnipeg, Churchill and Nelson Rivers Study Board, Tech. Rep. App. 5, Vol. 2. 100p.

Bennett, G. W. 1962. Management of artificial lakes and ponds. Chapman and Hall, London. 283p.

Benson, N. G. 1973. Evaluating the effects of discharge rates, water levels, and peaking on fish populations in Missouri River main stem impoundments, p. 683 - 689. In W. C. Ackermann, G. F. White, E. B. Worthington [eds.] Man-made lakes: their problems and environmental effects. Geophys. Monogr. 17. W. Byrd Press, Richmond, Virg.

von Bertalanffy, L. 1938. A quantitative theory of organic growth. Hum. Biol. 10: 181 - 213.

Brody, S. 1927. Growth rates. Univ. Missouri Agric. Exp. Sta. Bull. 97.

Cleugh, T. R. 1974. Hydrographic survey of lakes on the lower Churchill and Rat-Burntwood rivers and reservoirs and lakes on the Nelson River. Lake Winnipeg, Churchill and Nelson River Study Board, Tech. Rep. App. 5, Vol. 2, 230p.

Cowell, B. C., and P. L. Hudson. 1968. Some environmental factors influencing benthic invertebrates in two Missouri River reservoirs, p. 541 - 555. In C. E. Lane [ed.] Reservoir fishery resources symposium. Am.Fish. Soc., Wash., D. C.

Driver, E. A., and K. H. Doan. 1972. Fisheries survey of Cross Lake (Nelson River), 1965. Man. Dept. Mines, Res., and Env. Mgmt. Res. Br. MS Rep. 73-5, 17p.

Erickson, C. M. 1979. Age differences among three hard tissue structures observed in fish populations experiencing various levels of exploitation. Man. Dept. Nat. Res. MS Rep. 79-47, 31p.

Gaboury, M. N., and J. W. Patalas. 1981. An interim report on the fisheries impact study of Cross and Pipestone lakes. Man. Dept. Nat. Res. MS Rep. 81-22, 190p.

Hale, M. M., and D. R. Bayne. 1980. Effects of water level fluctuations on the littoral macroinvertebrates of West Point Reservoir. Proc. Ann. Conf. S. E. Assoc. Fish & Wildl. Agencies 34: 175 - 180.

Hamley, J. M. 1975. Review of gillnet selectivity. J. Fish. Res. Board Can. 32: 1943 - 1969.

Hutchinson, G. E. 1957. A treatise on limnology. Vol. 1. Chapman and Hall, London. 1015p.

Ioganzen, B. G. and A. V. Podlesnyi. 1958. Hydro construction in Siberia and problems of the fishing industry. Rybn. Khoz. 11: 21 - 26. FRB Transl. Ser. 227 (1959).

Jester, D. B. 1971. Effects of commercial fishing, species introductions, and drawdown control on fish populations in Elephant Butte reservoir, New Mexico, p. 265 - 285. In G. E. Hall [ed.] Reservoir fisheries and limnology. Am. Fish. Soc. Spec. Publ. 8.

June, F. C. 1970. Atresia and year-class abundance of northern pike, *Esox lucius*, in two Missouri River impoundments. J. Fish. Res. Board Can. 27: 587 - 591.

Lysack, W. 1980 . 1979 Lake Winnipeg fish stock assessment program. Man. Dept. Nat. Res. MS Rep. 80-30. 118p.

Machniak, K. 1975. The effects of hydroelectric development on the biology of northern fishes (reproduction and population dynamics). 1. Lake Whitefish, *Coregonus clupeaformis* (Mitchill). A literature review and bibliography. Can. Fish. Mar. Serv. Tech. Rep. 527, 67p.

Manitoba Water Resources Branch. Mean weekly water levels for major lakes in northern Manitoba. Dept. Nat. Res., Winnipeg, Man.

Robson, D. S., and D. G. Chapman. 1961. Catch curves and mortality rates. Trans. Am. Fish. Soc. 90: 181 - 189.

Smirnov, A. F. 1964. Rybokhoziastvennoe zmachenie vodokhranilishch Severnoi Karelii. (The importance of the fisheries in the reservoirs of North Karelia), p. 123 - 129. In Rybnoe khozyaistvo Karelii. Petrozavodsk. Vol. 8. (In Russian).

Snedecor, G. W., and W. G. Cochran. 1967. Statistical methods. 6th ed. Iowa State Univ. Press, Ames, Iowa. 593p.

Sunde, L. A. 1964. Walker Lake whitefish infestation. Man. Dept. Mines and Nat. Res. 2p.

Walford, L. A. 1946. A new graphic method of describing the growth of animals. Biol. Bull. 90(2): 141 - 147.

Whitehead, V. M. 1978. Stream crossing design and construction - implication to Manitoba fisheries. Man. Dept. Ren. Res. and Trans. Serv. Tech. Rep. 78-10, 173p.

ACKNOWLEDGMENTS

This study was funded by Manitoba Hydro, and, in part, by the Department of Natural Resources. Field assistance was provided by G. Spence, J. McLeod and A. McIvor. P. Flannagan identified and enumerated the benthos. B. Wright provided data from the 1977 Cross Lake survey. A. J. Derksen and J. F. O'Connor provided guidance and editorial comments in the preparation of this report. B. Bean typed this manuscript. The authors gratefully acknowledge the assistance of these individuals. In particular, the authors wish to thank Manitoba Hydro for their financial support, and D. B. Sinclair and M. C. McKay (Manitoba Hydro) for their cooperation. Also they wish to thank J. McLeod, A. McIvor, and B. Johanson who provided valuable information on the Cross and Pipestone lakes fisheries. The authors appreciate the cooperation of the Cross Lake fishermen who participated in the domestic fishing survey.

Appendix A1 . Water condition characteristics and plankton biomass for station 1 in Cross Lake, 1981.

	July 7	Aug. 9	Sept. 12
Depth (m)	1.9	1.7	2.1
Secchi (cm)	40	40	40
Temperature (C)			
surface	20.7	19.8	14.7
bottom	20.7	18.8	14.3
Conductivity (µmhos/cm)			
surface	106	118	107
bottom	106	118	108
Dissolved oxygen (mg/1)			
surface	8.8	8.8	9.7
bottom	8.7	8.1	9.2
Plankton biomass (mg/491 cm^2)			
replicate 1	94.2	8.6	14.2
replicate 2	99.0	13.9	17.5
replicate 3	123.1	18.7	12.8
mean	105.4	13.7	14.8

Appendix A2 . Water condition characteristics and plankton biomass for station 2 in Cross Lake, 1981.

	June 8	July 7	July 21	Aug. 9	Aug. 21	Sept. 12	Sept. 30
Depth (m)	0.8	1.5	1.5	1.4	1.3	1.8	2.0
Secchi (cm)	30	40	55	70	80	50	35
Temperature (C)							
surface	14.2	21.0	20.9	19.2	21.2	14.9	4.2
bottom	14.0	20.9	18.9	18.8	21.0	14.8	4.2
Conductivity (μmhos/cm)							
surface	62	109	113	92	108	129	99
bottom	72	109	110	92	109	129	99
Dissolved oxygen (mg/1)							
surface	10.4	8.8	9.4	8.8	8.8	10.5	13.6
bottom	10.2	8.8	10.0	8.8	8.7	10.4	13.6
Plankton biomass ($mg/491\ cm^2$)							
replicate 1	53.5	57.7	19.1	7.4	7.8	20.1	17.1
replicate 2	80.6	80.6	11.2	6.6	4.9	36.0	18.0
replicate 3	65.5	78.4	19.7	12.7	6.7	21.6	23.9
mean	66.5	72.2	16.7	8.9	6.5	25.9	19.7

Appendix A3. Water condition characteristics and plankton biomass for station 3 in Cross Lake, 1981.

	June 8	July 7	July 21	Aug. 9	Sept. 12
Depth (m)	6.5	7.3	7.3	7.0	7.5
Secchi (cm)	45	50	80	70	55
Temperature (C)					
surface	13.6	19.9	20.5	21.5	15.7
2 m	11.4	19.8	-	20.2	15.2
4 m	10.5	19.1	-	19.8	14.8
6 m	10.0	18.2	-	16.2	14.8
bottom	10.0	18.2	18.0	15.7	14.8
Conductivity (μmhos/cm)					
surface	69	112	110	109	152
2 m	62	112	-	109	151
4 m	60	112	-	109	149
6 m	60	111	-	109	150
bottom	60	111	-	110	151
Dissolved oxygen(mg/l)					
surface	9.7	8.4	9.8	9.0	9.0
2 m	8.9	8.2	-	7.2	8.9
4 m	8.3	7.6	-	7.2	8.2
6 m	6.5	7.2	-	0.1	7.8
bottom	4.8	6.4	6.8	0.0	7.6
Plankton biomass (mg/491 cm^2)					
replicate 1	90.4	245.7	-	23.2	46.7
replicate 2	91.3	180.8	-	24.5	56.9
replicate 3	104.2	320.7	-	26.0	60.1
mean	95.3	249.1	-	24.6	54.6

Appendix A4 . Water condition characteristics and plankton biomass for station 4 in Cross Lake, 1981.

	June 8	July 7	July 21	Aug. 9	Aug. 21	Sept. 12	Sept. 30
Depth (m)	1.5	2.2	2.1	2.0	2.0	2.4	2.5
Secchi (cm)	40	30	35	50	60	120	35
Temperature (C)							
surface	12.8	20.8	19.7	20.7	21.0	14.9	4.6
bottom	12.8	20.8	19.7	19.6	20.3	14.9	4.6
Conductivity (μmhos/cm)							
surface	68	180	168	164	152	257	179
bottom	68	180	168	159	149	256	179
Dissolved oxygen (mg/1)							
surface	10.3	8.6	9.9	10.2	9.8	10.0	13.6
bottom	10.2	8.6	9.7	9.9	9.1	10.0	13.3
Plankton biomass (mg/491 cm^2)							
replicate 1	49.6	99.7	22.4	23.5	17.9	9.9	16.2
replicate 2	48.1	114.0	24.0	22.9	16.7	12.2	17.7
replicate 3	77.2	105.5	27.0	28.6	14.4	9.9	14.7
mean	58.3	106.4	24.5	25.0	16.3	10.7	16.2

Appendix A5 . Water condition characteristics and plankton biomass for station 5 in Cross Lake, 1981.

	June 8	July 7	Aug. 9	Sept. 12
Depth (m)	1.4	2.1	1.9	2.2
Secchi (cm)	20	45	50	80
Temperature (C)				
surface	15.0	20.0	22.3	15.2
bottom	10.8	20.0	19.2	15.2
Conductivity (μmhos/cm)				
surface	60	193	172	245
bottom	58	193	164	241
Dissolved oxygen(mg/1)				
surface	10.6	8.8	10.7	10.8
bottom	9.4	8.7	8.0	9.9
Plankton biomass (mg/491 cm^2)				
replicate 1	25.0	32.4	18.6	6.0
replicate 2	25.0	27.9	20.9	12.7
replicate 3	23.7	38.6	21.9	8.6
mean	24.6	33.0	20.5	9.1

Appendix A6. Water condition characteristics and plankton biomass for station 6 in Cross Lake, 1981.

	June 10	July 10	Aug. 10	Sept. 13
Depth (m)	1.3	1.9	1.7	2.2
Secchi (cm)	65	55	70	70
Temperature (C)				
surface	12.4	18.2	20.7	14.8
bottom	12.4	18.1	20.7	14.8
Conductivity (μmhos/cm)				
surface	253	292	310	281
bottom	253	292	310	281
Dissolved oxygen(mg/1)				
surface	10.5	8.5	8.8	10.0
bottom	10.4	8.3	8.8	9.9
Plankton biomass (mg/491 cm^2)				
replicate 1	11.0	12.7	7.3	6.4
replicate 2	8.5	13.4	6.7	7.4
replicate 3	14.5	15.4	6.3	6.7
mean	11.3	13.8	6.8	6.8

Appendix A7. Water condition characteristics and plankton biomass for station 7 in Cross Lake, 1981.

	June 8	July 9	July 21	Aug. 9	Aug. 22	Sept. 13	Sept. 29
Depth (m)	3.6	5.3	5.0	4.5	4.1	5.3	5.5
Secchi (cm)	60	35	80	80	90	80	45
Temperature (C)							
surface	12.8	18.7	20.7	20.3	22.2	14.7	7.2
2 m	12.8	18.6	20.5	20.2	21.2	14.7	7.2
4 m	-	18.6	20.1	20.2	-	14.7	7.2
bottom	12.8	18.6	20.0	20.2	21.1	14.7	7.2
Conductivity (μmhos/cm)							
surface	245	278	308	299	308	281	221
2 m	247	278	307	297	300	281	221
4 m	-	278	303	297	-	281	221
bottom	248	280	303	297	298	281	221
Dissolved oxygen(mg/l)							
surface	9.4	8.5	8.4	8.6	8.3	9.7	11.9
2 m	9.4	8.5	8.3	8.5	8.3	9.6	11.8
4 m	-	8.4	8.2	8.5	-	9.6	11.7
bottom	9.3	8.3	8.2	8.4	8.2	9.6	11.7
Plankton biomass (mg/491 cm^2)							
replicate 1	16.6	73.8	-	15.2	4.8	12.3	13.1
replicate 2	18.8	63.7	22.2	13.0	5.4	12.4	10.7
replicate 3	11.6	67.7	19.6	14.7	6.0	11.9	22.1
mean	15.7	68.4	20.8	14.3	5.4	12.2	15.3

Appendix A8 . Water condition characteristics and plankton biomass for station 9 in Cross Lake, 1981.

	July 10	Aug. 10	Sept. 13
Depth (m)	3.0	3.0	3.3
Secchi (cm)	55	50	65
Temperature (C)			
surface	18.0	21.0	14.2
bottom	17.9	20.9	14.1
Conductivity (µmhos/cm)			
surface	302	320	277
bottom	302	320	278
Dissolved oxygen (mg/1)			
surface	8.5	8.9	9.3
bottom	8.4	8.7	9.2
Plankton biomass (mg/491 cm^2)			
replicate 1	14.8	19.2	18.2
replicate 2	24.6	18.5	13.0
replicate 3	36.2	26.7	12.6
mean	25.2	21.5	14.6

Appendix A9. Water condition characteristics and plankton biomass for station 10 in Cross Lake, 1981.

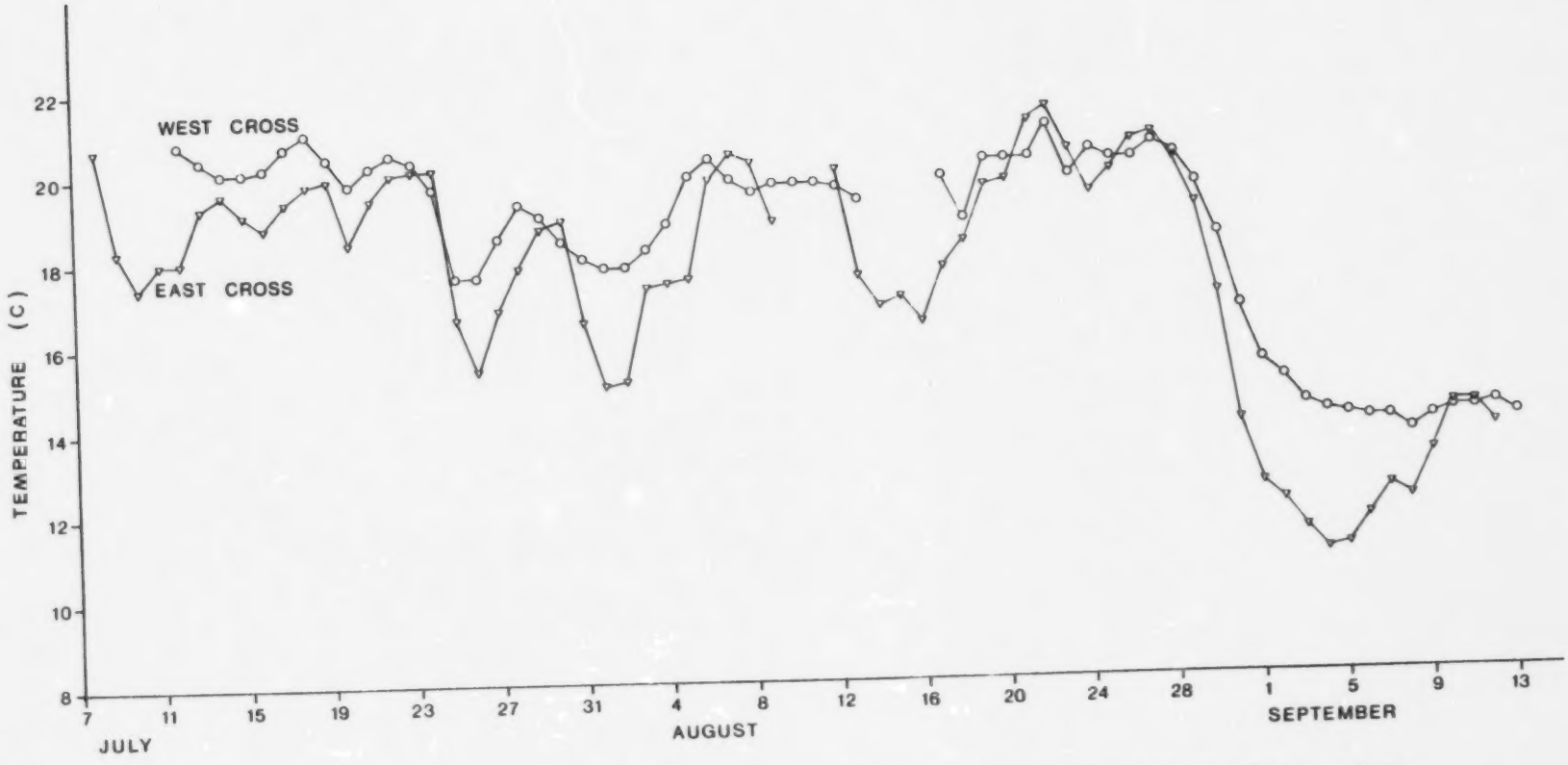
	June 7	July 10	July 22	Aug. 8	Aug. 22	Sept. 13	Sept. 29
Depth (m)	7.7	8.1	8.0	8.0	8.1	8.5	8.3
Secchi (cm)	300	130	150	160	130	150	160
Temperature (C)							
surface	13.0	18.8	21.0	20.1	21.9	15.8	9.2
2 m	13.0	18.5	21.0	20.0	20.8	15.8	9.2
4 m	13.0	18.5	20.8	19.9	20.7	15.8	9.2
6 m	13.0	18.5	20.5	19.8	19.8	15.8	9.2
bottom	12.9	18.3	20.2	19.6	19.5	15.8	9.2
Conductivity(μmhos/cm)							
surface	235	252	270	261	272	242	208
2 m	235	253	270	261	266	242	208
4 m	235	255	270	261	267	242	210
6 m	235	255	272	261	265	242	210
bottom	238	255	276	257	262	242	210
Dissolved oxygen (mg/l)							
surface	-	8.4	9.5	8.2	9.9	10.0	11.6
2 m	-	8.4	9.4	8.1	9.2	9.8	11.5
4 m	-	8.3	9.2	7.9	8.4	9.8	11.4
6 m	-	8.3	8.3	7.3	5.0	9.7	11.4
bottom	-	8.0	6.5	5.9	4.5	9.6	11.4
Plankton biomass (mg/491 cm^2)							
replicate 1	59.4	198.8	108.6	81.8	175.1	181.2	167.6
replicate 2	57.5	236.9	95.4	76.7	178.1	168.1	130.7
replicate 3	61.8	236.0	101.3	83.6	162.4	188.4	184.4
mean	59.6	223.9	101.8	80.7	171.9	179.2	160.9

Appendix A10. Water condition characteristics and plankton biomass for station 11 in Pipestone Lake, 1981.

	June 10	July 10	July 22	Aug. 8	Aug. 22	Sept. 14	Sept. 29
Depth (m)	1.0	1.7	1.5	1.7	1.7	2.2	1.9
Secchi (cm)	45	70	120	100	100	65	80
Temperature (C)							
surface	11.2	19.5	20.8	19.4	21.9	13.0	7.1
bottom	11.2	19.5	20.3	19.4	20.3	13.0	7.1
Conductivity (μmhos/cm)							
surface	248	290	313	289	302	242	213
bottom	248	290	311	289	293	242	213
Dissolved oxygen (mg/l)							
surface	10.8	9.2	9.0	10.2	8.4	10.6	12.3
bottom	10.8	9.2	9.2	9.9	8.4	10.6	12.3
Plankton biomass (mg/491 cm^2)							
replicate 1	27.4	5.6	13.8	12.2	2.3		4.4
replicate 2	29.2	8.4	11.3	14.3	2.1		1.9
replicate 3	33.1	4.7	9.1	10.2	2.5		3.0
mean	29.9	6.3	11.4	12.2	2.3		3.1

Appendix A11. Water condition characteristics and plankton biomass for station 12 in Walker Lake, 1981.

	June 8	June 22	June 28	Aug. 3	Sept. 3
Depth (m)	6.4	7.0	7.1	6.9	5.5
Secchi (cm)	310	360	340	230	150
Temperature (C)					
surface	12.7	14.2	17.0	19.3	15.0
2 m	11.8	13.3	15.7	19.2	15.1
4 m	11.7	11.8	15.2	18.9	15.1
6 m	11.3	11.3	14.3	17.5	-
bottom	11.0	11.1	13.6	17.2	15.1
Conductivity (µmhos/cm)					
surface	103	106	121	113	-
2 m	103	105	118	113	-
4 m	103	102	117	113	-
6 m	102	102	116	112	-
bottom	102	102	114	112	-
Dissolved oxygen (mg/1)					
surface	10.4	10.4	9.7	9.7	10.0
2 m	10.3	10.6	10.0	9.6	9.7
4 m	10.2	10.6	9.9	9.6	9.6
6 m	10.1	9.8	8.8	8.9	-
bottom	10.1	9.6	7.6	8.4	9.5
Plankton biomass (mg/491 cm^2)					
replicate 1	44.2	161.2	137.3	48.4	155.0
replicate 2	136.3	154.4	147.3	49.7	172.3
replicate 3	171.6	158.7	144.4	44.4	161.3
mean	117.4	158.1	143.0	47.5	162.9



Appendix A12. Maximum daily bottom water temperatures in the west and east basins of Cross Lake. East Cross measurements are from station 2 and west Cross are from close to netting location # 49.

Appendix A13. Water chemistry data for station 2, 1981.

Parameter	Mar. 6	June 7	July 8	Aug. 9	Sept. 12
Conductivity (μmho/cm)	257	81	120	105	167
Total dissolved solids (mg/l)	180	61	102	65	130
Total suspended solids (mg/l)	15	41	44	25	26
pH	7.30	7.70	8.05	8.95	9.20
Alkalinity ($CaCO_3$)(mg/l)	96	36	45	50	59
Alkalinity (HCO_3)(mg/l)	117	44	55	54	62
Organic carbon - total (mg/l)	17.5	19.0	18.0	14.5	22.0
Organic carbon - dissolved(mg/l)	15.5	12.0	12.5	14.5	15.0
Phosphorus-total (mg/l)	0.05	0.10	0.05	0.05	0.04
Phosphorus-dissolved (mg/l)	0.04	0.03	-	0.02	0.02
Nitrogen-total (mg/l)	0.9	0.9	1.0	0.7	1.3
Nitrogen-dissolved (mg/l)	0.9	0.6	0.7	0.7	0.9
Nitrate-Nitrite-dissolved(mg/l)	0.2	<0.01	<0.01	<0.01	<0.01
Sulphate-soluble (mg/l)	25.0	10.0	16.5	3.3	27.0
Chloride-soluble (mg/l)	14	2	2	<2	6
Sodium-extractable (mg/l)	15	<10	<10	<5	<10
Calcium-extractable (mg/l)	30	10	18	15	20
Potassium-extractable (mg/l)	3.0	< 2.0	<1.0	<1.0	<2.0
Magnesium-extractable (mg/l)	9	< 5	5	5	5
Manganese-extractable (mg/l)	0.03	0.02	<0.02	<0.02	0.03
Iron-extractable (mg/l)	0.16	0.92	0.48	0.20	0.28
Silica-soluble reactive (mg/l)	<0.4	0.2	1.2	0.4	0.2

Appendix A14. Water chemistry data for station 4, 1981.

Parameter	Mar. 6	June 7	July 8	Aug. 9	Sept. 12
Conductivity (µmho/cm)	199	90	200	177	316
Total dissolved solids (mg/l)	170	57	147	125	220
Total suspended solids (mg/l)	8	27	41	5	<5
pH	7.20	7.65	8.15	9.70	8.50
Alkalinity ($CaCO_3$)(mg/l)	86	38	62	59	101
Alkalinity (HCO_3)(mg/l)	105	46	76	48	118
Organic carbon - total (mg/l)	16.0	14.5	16.0	19.0	11.0
Organic carbon - dissolved (mg/l)	13.5	10.5	11.5	12.5	10.0
Phosphorus - total (mg/l)	0.02	0.10	0.08	0.06	0.03
Phosphorus - dissolved (mg/l)	-	0.06	-	0.03	0.02
Nitrogen - total (mg/l)	0.7	0.8	0.7	1.2	0.6
Nitrogen - dissolved (mg/l)	-	0.6	-	0.7	0.6
Nitrate - nitrite - dissolved (mg/l)	0.12	<0.01	<0.01	<0.01	<0.01
Sulphate - soluble (mg/l)	-	10.0	18.0	25.0	37.0
Chloride - soluble (mg/l)	-	2	10	6	21
Sodium - extractable (mg/l)	-	<10	-	8	20
Calcium - extractable (mg/l)	-	10	-	18	30
Potassium - extractable (mg/l)	-	<2.0	-	1.5	2.3
Magnesium - extractable (mg/l)	-	25	-	8	13
Manganese - extractable (mg/l)	-	<0.02	-	<0.02	0.02
Iron - extractable (mg/l)	-	0.66	-	0.09	0.15
Silica - soluble reactive (mg/l)	-	0.3	3.1	0.4	1.0

Appendix A15. Water chemistry data for station 7, 1981.

Parameter	Mar. 6	June 8	July 9	Aug. 9	Sept. 13
Conductivity (μmho/cm)	353	305	305	313	331
Total dissolved solids (mg/l)	210	194	191	205	220
Total suspended solids (mg/l)	7	16	41	15	9
pH	8.10	8.15	8.30	8.45	8.45
Alkalinity ($CaCO_3$)(mg/l)	120	104	103	104	107
Alkalinity (HCO_3)(mg/l)	146	127	126	124	123
Organic carbon - total (mg/l)	11.5	11.0	11.5	10.0	10.5
Organic carbon - dissolved (mg/l)	11.5	10.5	11.0	9.0	9.0
Phosphorus - total (mg/l)	0.03	0.04	0.04	0.03	0.03
Phosphorus - dissolved (mg/l)	-	0.03	-	0.02	0.02
Nitrogen - total (mg/l)	0.4	0.5	0.6	0.4	0.5
Nitrogen - dissolved (mg/l)	-	0.5	0.5	0.5	0.5
Nitrate - nitrite - dissolved (mg/l)	0.05	<0.01	<0.01	<0.01	<0.01
Sulphate - soluble (mg/l)	-	29.0	20.5	28.0	37.0
Chloride - soluble (mg/l)	-	19	19	21	23
Sodium - extractable (mg/l)	-	<10	20	19	20
Calcium - extractable (mg/l)	-	28	28	30	33
Potassium - extractable (mg/l)	-	2.8	3.6	2.6	2.3
Magnesium - extractable (mg/l)	-	10	13	13	13
Manganese - extractable (mg/l)	-	0.02	0.03	<0.02	0.02
Iron - extractable (mg/l)	-	0.48	0.56	0.18	0.31
Silica - soluble reactive (mg/l)	-	4.0	11.3	0.9	3.7

Appendix A16. Water chemistry data for station 10, 1981.

Parameter	June 10	July 9	Aug. 8	Sept. 13
Conductivity (µmho/cm)	273	268	270	287
Total dissolved solids (mg/l)	180	176	180	200
Total suspended solids (mg/l)	<5	<5	10	5
pH	8.10	8.15	8.35	8.50
Alkalinity ($CaCO_3$) (mg/l)	94	91	96	91
Alkalinity (HCO_3) (mg/l)	115	111	115	106
Organic carbon - total (mg/l)	12.0	14.5	12.5	12.0
Organic carbon - dissolved (mg/l)	10.5	11.5	11.0	10.0
Phosphorus - total (mg/l)	0.03	0.04	0.03	0.04
Phosphorus - dissolved (mg/l)	0.03	-	0.02	0.02
Nitrogen - total (mg/l)	0.4	0.5	0.5	0.6
Nitrogen - dissolved (mg/l)	0.3	0.5	0.5	0.5
Nitrate - Nitrite - dissolved (mg/l)	<0.01	0.01	<0.01	<0.01
Sulphate - soluble (mg/l)	28.0	16.5	20.0	32.0
Chloride - soluble (mg/l)	14	16	16	18
Sodium - extractable (mg/l)	13	15	16	13
Calcium - extractable (mg/l)	23	23	28	30
Potassium - extractable (mg/l)	3.0	3.0	2.3	2.0
Magnesium - extractable (mg/l)	8	10	10	10
Manganese - extractable (mg/l)	<0.02	<0.02	<0.02	<0.02
Iron - extractable (mg/l)	0.08	0.08	0.18	0.08
Silica - soluble reactive (mg/l)	4.3	2.2	2.8	4.0

Appendix A17. Water chemistry data for station 11, 1981.

Parameter	June 10	July 9	Aug. 8	Sept. 13
Conductivity (µmho/cm)	313	302	308	313
Total dissolved solids (mg/l)	212	189	195	220
Total suspended solids (mg/l)	48	21	15	8
pH	8.20	8.30	8.50	8.40
Alkalinity ($CaCO_3$)(mg/l)	110	101	103	100
Alkalinity (HCO_3)(mg/l)	134	123	118	112
Organic carbon - total (mg/l)	10.5	12.5	10.5	11.5
Organic carbon - dissolved (mg/l)	10.0	11.5	8.5	10.0
Phosphorus - total (mg/l)	0.06	0.05	0.03	0.03
Phosphorus - dissolved (mg/l)	0.03	-	0.02	0.02
Nitrogen - total (mg/l)	0.4	0.5	0.4	0.5
Nitrogen - dissolved (mg/l)	0.3	0.5	0.5	0.5
Nitrate - Nitrite - dissolved (mg/l)	<0.01	<0.01	<0.01	<0.01
Sulphate - soluble (mg/l)	30.0	20.5	25.5	37.0
Chloride - soluble (mg/l)	21	19	21	22
Sodium - extractable (mg/l)	25	20	19	20
Calcium - extractable (mg/l)	28	30	30	30
Potassium - extractable (mg/l)	4.0	3.3	2.4	2.3
Magnesium - extractable (mg/l)	10	13	13	13
Manganese - extractable (mg/l)	0.03	0.02	<0.02	0.03
Iron - extractable (mg/l)	0.48	0.53	0.09	0.28
Silica - soluble reactive (mg/l)	1.1	1.8	0.7	1.2

Appendix A18. Water chemistry data for station 12, 1981.

Parameter	Mar. 6	June 9	June 28	Aug. 3	Sept. 3
Conductivity (µmho/cm)	151	136	132	130	127
Total dissolved solids (mg/l)	100	82	92	100	96
Total suspended solids (mg/l)	<5	<5	<5	<5	<5
pH	7.7	8.05	8.00	8.55	8.40
Alkalinity ($CaCO_3$)(mg/l)	72	71	65	63	64
Alkalinity (HCO_3^-)(mg/l)	88	87	79	74	73
Organic carbon - total (mg/l)	20.0	12.0	17.5	13.5	14.5
Organic carbon - dissolved (mg/l)	12.5	11.5	15.0	13.0	12.5
Phosphorus - total (mg/l)	0.03	0.04	0.03	0.02	0.03
Phosphorus - dissolved (mg/l)	0.03	0.02	0.02	<0.02	0.02
Nitrogen - total (mg/l)	0.5	0.5	0.5	0.5	0.6
Nitrogen - dissolved (mg/l)	0.5	0.5	0.5	0.4	0.4
Nitrate - Nitrite - dissolved (mg/l)	0.08	<0.01	<0.01	<0.01	<0.01
Sulphate - soluble (mg/l)	5	7.0	2.5	10.0	2.5
Chloride - soluble (mg/l)	<2	<2	<2	<2	<2
Sodium - extractable (mg/l)	<10	<10	<10	<10	<10
Calcium - extractable (mg/l)	18	18	20	20	20
Potassium - extractable (mg/l)	<2.0	<2.0	<1.0	<2.0	<2.0
Magnesium - extractable (mg/l)	<5	<5	8		5
Manganese - extractable (mg/l)	<0.02	0.03	0.02	0.02	0.07
Iron - extractable (mg/l)	0.05	0.10	0.10	0.08	0.14
Silica - soluble reactive (mg/l)	<0.4	4.3	1.6	1.2	2.2

Appendix A19. Number of benthic organisms per Ekman dredge (523 cm^2) in stations 1, 2 and 3.

Organism	Station 1			Station 2				Station 3			
	July 7	Aug. 9	Sept. 12	June 8	July 7	Aug. 9	Sept. 12	June 8	July 7	Aug. 9	Sept. 12
Annelida											
Hirudinea	2	2	4	1	2	1	4	1	1	-	1
Oligochaeta	2	1	-	1	-	12	3	24	17	20	11
Arthropoda											
Cladocera	12	2	-	1	-	-	-	9	6	-	-
Copepoda	-	-	-	-	-	-	-	-	1	-	-
Amphipoda	-	-	-	-	-	-	-	-	-	-	-
Hyalella azteca	8	75	111	38	66	375	124	12	2	-	-
Gammarus lacustris	-	-	-	-	-	1	-	-	-	-	-
Ostracoda	-	4	-	1	1	4	1	-	-	2	-
Arachnidae	-	-	-	-	-	-	-	-	-	-	-
Acarina	-	-	-	-	-	-	-	-	-	-	-
Diptera											
Ceratopogonidae	-	-	-	-	-	1	3	-	-	3	-
Chaoboridae	-	-	-	-	-	-	-	-	-	-	1
Chironomidae	26	163	98	65	27	163	56	137	54	582	8
Ephemeroptera											
Hexagenia	-	-	-	-	-	-	-	-	-	-	-
Hemiptera											
Corixidae	-	-	-	-	-	-	-	1	1	-	-
Trichoptera	-	-	4	1	2	-	-	-	-	-	-
Mollusca											
Gastropoda	1	1	1	-	-	7	2	-	-	-	-
Pelecypoda											
Sphaeriidae	7	1	4	11	8	14	7	3	5	9	12
Unionidae	-	-	-	-	-	-	-	-	-	-	-
Nematoda	14	42	12+	29	1	-	6	9	13	11	

Appendix A20. Number of benthic organisms per Ekman dredge (523 cm^2) in station 4, 5 and 6.

Organism	Station 4				Station 5				Station 6			
	June 8	July 7	Aug. 9	Sept. 12	June 8	July 7	Aug. 9	Sept. 12	June 10	July 10	Aug. 10	Sept. 13
Annelida												
Hirudinea	2	1	2	-	-	2	-	1	11	1	1	1
Oligochaeta	8	2	1	-	2	8	-	3	-	-	-	-
Arthropoda												
Cladocera	-	-	1	-	-	1	-	-	-	-	-	-
Copepoda	-	-	-	-	-	-	-	-	-	-	-	-
Amphipoda												
Hyalella azteca	13	4	3	-	-	1	-	-	-	1	-	-
Pontoporeia hoyi	-	-	-	-	-	-	-	-	-	74	12	26
Ostracoda	-	1	7	10	-	-	1	-	-	-	-	-
Arachnidae	1	-	-	-	-	-	-	-	-	-	-	-
Acarina	1	-	-	-	-	-	-	-	-	-	-	-
Diptera												
Ceratopogonidae	2	2	-	1	6	-	1	-	2	-	-	-
Chaoboridae	-	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	191	130	41	85	95	44	14	-	9	19	8	16
Ephemeroptera												
Hexagenia	-	-	-	1	26	12	6	7	3	15	4	10
Hemiptera												
Corixidae	1	1	-	-	-	-	-	-	-	-	1	-
Trichoptera	4	1	-	-	2	1	-	-	3	-	1	4
Mollusca												
Gastropoda	7	25	4	2	72	23	54	63	239	39	145	420
Pelecypoda												
Sphaeriidae	8	16	4	4	83	39	80	31	123	259	300	464
Unionidae	-	-	-	-	-	-	-	-	-	1	-	-
Nematoda	4	23	2	-	113	76	68	54	1	1	-	1

Appendix A21. Number of benthic organisms per Ekman dredge (523 cm^2) in station 7, 9 and 10.

Organism	Station 7				Station 9			Station 10			
	June 8	July 9	Aug. 9	Sept. 13	July 10	Aug. 10	Sept. 13	June 7	July 10	Aug. 8	Sept. 13
Annelida											
Hirudinea	1	-	-	2	-	-	-	1	-	-	-
Oligochaeta	-	-	1	-	-	-	-	-	20	42	45
Arthropoda											
Cladocera	-	-	-	-	-	-	-	-	-	4	-
Copepoda	-	-	-	-	-	-	-	-	-	-	-
Amphipoda											
Hyalella azteca	-	-	-	-	-	-	-	-	-	-	-
Pontoporeia hoyi	-	2	30	13	-	2	1	-	-	-	-
Ostracoda	-	-	-	-	-	1	-	-	2	15	-
Arachnidae											
Acarina	-	-	-	-	-	-	-	-	-	-	-
Diptera											
Ceratopogonidae	-	-	2	-	1	2	-	4	-	1	-
Chaoboridae	-	-	-	-	-	-	-	-	-	-	-
Chironomidae	4	12	16	39	36	70	51	11	95	180	183
Ephemeroptera											
Hexagenia	4	13	19	1	34	23	14	7	1	2	6
Hemiptera											
Corixidae	-	-	-	-	-	-	-	-	-	-	-
Trichoptera	-	-	-	-	-	-	1	2	-	-	-
Mollusca											
Gastropoda	20	24	31	216	35	22	139	19	7	3	3
Pelecypoda											
Sphaeriidae	40	42	63	159	20	98	54	42	9	23	5
Unionidae	-	-	-	3	-	-	1	-	-	-	-
Nematoda	-	-	-	-	-	-	-	-	12	8	-

Appendix A22. Number of benthic organims per Ekman dredge (523 cm^2) in stations 11 and 12.

Organism	Station 11				Station 12			
	June 7	July 10	Aug. 8	Sept. 14	June 12	June 28	Aug. 3	Sept. 13
Annelida								
Hirudinea	–	1	–	4	–	–	–	1
Oligochaeta	26	–	–	–	3	5	1	2
Arthropoda								
Cladocera	–	–	–	–	–	–	–	1
Copepoda	–	–	–	–	–	–	–	–
Amphipoda								
Hyalella azteca	1	–	–	–	–	–	–	2
Pontoporeia hoyi	–	–	–	7	–	–	–	–
Ostracoda	–	–	–	–	–	–	–	6
Arachnidae								
Acarina	1	–	–	–	–	–	–	–
Diptera								
Ceratopogonidae	–	2	1	3	–	–	–	–
Chaoboridae	4	–	–	–	–	–	–	8
Chironomidae	147	8	12	55	23	67	3	97
Ephemeroptera								
Caenis	–	–	–	–	–	–	–	1
Hexagenia	–	–	6	51	–	–	–	–
Hemiptera								
Corixidae	–	–	–	–	–	–	–	–
Trichoptera	–	1	–	9	–	–	–	–
Mollusca								
Gastropoda	3	15	71	227	–	–	–	–
Pelecypoda								
Sphaeriidae	33	48	166	200	5	30	4	80
Unionidae	–	–	–	–	–	–	–	–
Nematoda	23	8	2	–	2	9	42	23

Appendix B1. Summary of commercial fish production from Walker Lake, 1942 - 1979 (based on Manitoba Govt. records).

Period	Years of Record/Fishing	No. of Licences Summer/Winter	Marketed Fish Production (kg)				
			Whitefish	Walleye	Pike	Others*	Total
1942-1945 Total	3/3	0/30	95209	3357		45	98611
Mean Annual		0/10	31736	1119		15	32870
1945-1950	5/5	0/135	344367	73437	10070		327874
Mean Annual		0/27	68873	14687	2014		85574
1950-1955	5/5	0/116	327630	32296		181	360107
Mean Annual		0/23	65526	6459		36	72021
1955-1960	5/5	49/70	161570	66088	3402		231060
Mean Annual		10/14	32314	13218	680		46212
1960-1965	5/4	43/17	90038	58559	3583		152180
Mean Annual		11/14	22509	14640	896		38045
1965-1970	5/5	63/10	130045	29665	8210		167920
Mean Annual		13/2	26009	5933	1642		33584
1970-1975	4/4	41/3	25537	54386	6940		86863
Mean Annual		10/0.7	6384	13596	1735		21715
1975-1976	1/1	14/3	5346	3061	236		8643
1976-1977	1/1	5/3	5356	2598	3533	1	11488
1977-1978	1/1	0/8	4290	1991	9669	64	16014
1979	1/1	10/0	11348	10914	3381	104	25747

* other fish included cisco, perch and sauger

Appendix B2 . Catch summaries for experimental fishing sets in Walker Lake, 1981.

Set Location	Date of set	Whitefish	Cisco	Northern Pike	Walleye	Sauger	Yellow Perch	White Sucker	Burbot	Total
1	June 11		27	20	7			23		77
2	June 12		20	19	17		10	38		104
3	June 13		3	9	10			14	5	41
4	June 14	7	19	14	7		9	12		68
5	June 14	2	40	19	9			51	1	122
6	June 15		2	18	4			8		32
7	June 15		2	10	5	3		23	1	44
8	June 16	1	13	26	3	1		10		54
9	June 16			6	5	1		16		28
10	June 18		5	28	10	2		35		80
11	June 18		16	26		1		13		56
12	June 19	3	7	20	3		1	29		63
13	June 19	1	7	28	2			15	1	54
14	June 20		10	10	2			30		52
15	June 20	1	7	26	4		1	35		74
16	June 23		1	17	3		8	18		47
17	June 23	2	14	19	2		1	24		62
18	June 24	3	9	22	1	2		14	2	53
19	June 24	58	8	8	2	2		1	9	88
20	June 25	14	14	9		4		5	5	51
21	June 25	12	7	11	3	2		15	1	51
22	June 26		26	12	7		1	7		53
23	June 26	1	24	15	7	1		10		58
24	June 27	4	18	7	1	3		5	1	39
25	June 27	12	21	21		3		9		66
Total caught		121	320	420	114	25	31	460	26	1517
Total sampled		121	278	258	114	25	-	-	-	796
Total aged		121	275	258	113	24	-	-	-	791

Appendix B3 . Catch summaries for experimental fishing sets in the west basin of Cross Lake, 1981.

Set Location	Date of set	Whitefish	Cisco	Northern pike	Walleye	Sauger	Yellow perch	White sucker	Longnose sucker	Shorthead Redhorse	Mooneye	Burbot	Freshwater Drum	Total
26	July 10	12	1	3	3	6	1	43	1	3	7			80
27	July 11	2		5	9	2	2	5	1	4	5			35
28	July 12	3				13		43	8		1	1		69
29	July 13	1			3	1	1	3		1				10
30	July 13	3		2		7	1	39	20				1	73
31	July 14			1	1	2		2		1				7
32	July 14				1		1	2		2				6
33	July 15	9	80	16	26	1	18	6						156
34	July 16		48	13	25		22	7						115
35	July 17	2	21	9	11		19	2						64
36	July 17	7	57	14	36		20	7						141
37	July 18	4	89	12	19		13	10						147
38	July 19		38	12	29	5	34	15						133
39	July 20	7	54	13	59			13		1				147
40	July 20	10	22	7	49			14		1	12		1	116
41	July 22	5	38	6	30			5		2	2			88
42	July 22	14	62	9	23	3		5						116
43	July 23	13	85	26	28	4		13		3			1	173
44	July 23	21	169	16	61	4		8			1		3	283
45	July 26	5	53	10	43		4	10		1	2		1	129
46	July 26	1	37	20	50	1		17		3	7			136
47	July 27	13	12	9	49			10		1				94
48	July 27	1	28	15	30			12		8	2			96
49	July 28	1		2	1		1	8		2	1			16
50	July 29	3	1	4	4	2	1	7		6	2			30
51	July 29	3	41	24	29	1	1	5						104
52	July 30	2	1	13	6	1	3	5						31
53	July 30			4	6		2	7		4				23
Total caught		142	937	265	631	53	144	323	30	43	42	1	7	2618
Total sampled		141	320	261	275	53	-	-	-	-	-	-	-	1050
Total aged		140	320	261	275	53	-	-	-	-	-	-	-	1049

Appendix B4. Catch summaries for experimental fishing sets in the east basin of Cross Lake, 1981.

Set Location	Date of set	Whitefish	Cisco	Northern Pike	Walleye	Sauger	Yellow Perch	White Sucker	Longnose sucker	Shorthead Redhorse	Goldeye	Mooneye	Freshwater Drum	Carp	Total
54	Aug. 11	4	120	11	17	1		2		1					156
55	Aug. 11	3	72	9	20	1		5		1					111
56	Aug. 12	13	41	6	21			5		1					87
57	Aug. 12		42	8	29			10		1					89
58	Aug. 12	2	29	5	51			8							96
59	Aug. 13	4	72	5	33			7		1					123
60	Aug. 13	2	53	17	29		1	3	1		2				106
61	Aug. 13	2	38	14	20		1	3					1		79
62	Aug. 14	1	40	3	34			4		2					84
63	Aug. 17	8	42	4	63			15							132
64	Aug. 17	2	43	4	20			9							78
65	Aug. 17	2	34	3	23			11				1			74
66	Aug. 18	8	60	3	24			4		1		1			101
67	Aug. 18	6	37	4	16			10							73
68	Aug. 18	10	14	6	35			27				1			93
69	Aug. 19			5	54			21							80
70	Aug. 19	17	52	3	29		1	13		1					116
71	Aug. 19	13	26	8	24			6		3					80
72	Aug. 20	18	51	5	28		1	22							125
73	Aug. 20	20	46	6	21			8			1	1			103
74	Aug. 23	7	21	4	42			13							87
75	Aug. 23		7	6	55			5			3	4			80
76	Aug. 23	1	18	9	80			16			3	1			128
77	Aug. 24	15	20	9	49			7		1	1			1	103
78	Aug. 24		19	6	67		3	39		3			2		139
Total caught		158	997	163	884	2	7	273	1	15	10	9	3	1	2523
Total sampled		158	297	163	322	2	–	–	–	–	–	–	–	–	942
Total aged		155	294	163	320	2	–	–	–	–	–	–	–	–	934

Appendix B5 . Catch summaries for experimental fishing sets in Pipestone Lake, 1981.

Set Location	Date of set	Whitefish	Cisco	Northern Pike	Walleye	Sauger	Yellow Perch	White Sucker	Longnose Sucker	Shorthead Redhorse	Goldeye	Mooneye	Burbot	Freshwater Drum	Carp	Total
79	Aug.26			7	17	1	3	2		6		12				48
80	Aug.26	1		6	14		14	3				8		4	1	51
81	Aug.27	1	2	4	10	2				1	1	39				60
82	Aug.27			4	7	1	4	4		1	1	2				24
83	Aug.31				3				9							12
84	Aug.31		1		1	1		5			1	3	1			13
85	Aug.31		1	1	6											8
86	Sept.1	4		6	17	1	2	12				9				51
87	Sept.1	1	3	3	16	1	6	4		3		28		1		66
88	Sept.1	2		10	4		6	34	1							57
89	Sept.14	2		3	4	1	1	4			1	5				21
90	Sept.14		3	1	10	1		1	1			8	1			26
91	Sept.15		16	7	13			6		3		5				50
92	Sept.15	1	5	1	8	2		9		3		2				31
93	Sept.16		1	6	12		4	6		1	1	30		1		62
94	Sept.16			2	3			3				7		1		16
95	Sept.17							2		1				4	1	8
96	Sept.17				2			2		1		1		3		9
97	Sept.20	1		8	5		3	13								30
98	Sept.20	3		8	11		2	6								30
99	Sept.21		3	6	22	1	2	6			3		1			44
100	Sept.21	6	2	4	5		2	10								29
101	Sept.22	4	3	5	8		3	18								41
102	Sept.22	1	5	5	4			7			1		1	1		25
103	Sept.23	1	2	2	4			8		1		1	1	1		21
104	Sept.23	6	10	7	10		4	10		1						48
105	Sept.24	1	9	10	3		1	3				2		1		30
106	Sept.24	1	7	10	10			9				6		2		45
Total caught		36	73	126	229	12	57	187	11	22	9	168	5	19	2	956
Total sampled		36	73	126	229	12	-	-	-	-	-	-	-	-	-	476
Total aged		36	73	126	229	12	-	-	-	-	-	-	-	-	-	476

Appendix B6 . Mesh size effects on whitefish catches in the west basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	4	23	15	24	27	26	23
CUE* (number/100 yds/16 hrs)	0.57	3.29	2.14	3.43	3.86	3.71	3.29
CUE* (kg/100 yds/16 hrs)	0.07	1.68	2.29	4.83	6.35	6.56	6.18
Mean length (mm)	203.00	269.57	387.40	434.17	459.85	465.27	482.05
Mean weight (g)	117.50	512.61	1070.67	1409.58	1646.30	1765.77	1881.82
% Immature	100.0	78.3	46.7	29.2	11.1	7.7	4.3
Mean age (years)	1.75	3.87	5.93	7.78	8.78	8.73	10.55
Age	Frequency (%)						
1	25.00						
2	75.00	78.26	13.33				
3			26.67	21.74	3.70		
4			6.67		3.70	3.85	
5			6.67	4.35	3.70	3.85	4.55
6				13.04	11.11	3.85	4.55
7		4.35	6.67	13.04	18.52	23.08	13.64
8		4.35	13.33	8.70	3.70	15.38	9.09
9			6.67	4.35	22.22	19.23	13.64
10				8.70	7.41	3.85	9.09
11			13.33	8.70	3.70	19.23	4.55
12		8.70	6.67	8.70	11.11		9.09
13					3.70	3.85	9.09
14		4.35		4.35	3.70		13.64
15				4.35		3.85	4.55
16					3.70		
17							
18							
19							4.55

* the total effort was 700 yards for each mesh

Appendix B7 . Mesh size effects on whitefish catches in the east basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	5	9	25	23	32	34	30
CUE* (number/100 yds/16 hrs)	0.80	1.44	4.00	3.68	5.12	5.44	4.8
CUE* (kg/100 yds/16 hrs)	0.95	2.18	4.13	5.47	9.66	10.21	9.86
Mean length (mm)	392.60	410.56	371.44	412.65	460.88	460.85	478.93
Mean weight (g)	1192.00	1513.33	1032.40	1486.52	1887.19	1876.18	2053.33
% Immature	60.0	44.4	60.0	43.5	28.1	20.6	6.7
Mean age (years)	4.20	5.11	4.24	5.78	7.45	7.24	7.66
Age	Frequency (%)						
2	20.00	11.11	40.00	17.39			
3	40.00	33.33	20.00	17.39	22,58	15.15	3.45
4				4.35	3.23	3.03	
5				4.35			3.45
6	20.00		8.00	8.70	12.90	15.15	17.24
7	20.00	55.56	24.00	30.43	22.58	33.33	44.83
8			4.00		9.68	6.06	3.45
9			4.00		3.23	6.06	13.79
10				8.70	3.23		
11				4.35	6.45	15.15	3.45
12				4.35	3.23	6.06	3.45
13					3.23		6.90
14					6.45		
15					3,23		

* the total effort was 625 yards for each mesh

Appendix B8. Mesh size effects on whitefish catches in Pipestone Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	1	1	0	4	6	12	12
CUE* (number/100 yds/16 hrs)	0.14	0.14		0.57	0.86	1.71	1.71
CUE* (kg/100 yds/16 hrs)	0.06	0.27		1.02	1.98	3.48	3.36
Mean length (mm)	300.00	471.00		476.75	505.50	489.08	483.42
Mean weight (g)	430.00	1880.00		1792.50	2310.00	2028.33	1959.17
% Immature	100.00	0.0		25.0	0.0	0.0	0.0
Mean age (years)	3.00	10.00		11.00	11.67	11.00	11.42
Age	Frequency (%)						
3	100.00						
4							
5							
6							8.33
7				25.00	16.67	8.33	8.33
8						16.67	
9		100.00				25.00	33.33
10				25.00	16.67	8.33	8.33
11				25.00	33.33	16.67	8.33
12				25.00	16.67	16.67	
13					16.67		16.67
14						8.33	8.33
15							8.33
16							

* the total effort was 700 yards for each mesh

Appendix B9 . Mesh size effects on whitefish catches in Walker Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	1	6	13	17	22	33	29
CUE* (number/100 yds/16 hrs)	0.16	0.96	2.08	2.72	3.52	5.28	4.64
CUE* (kg/100 yds/16 hrs)	0.02	1.02	3.81	4.39	7.04	10.08	9.60
Mean length (mm)	218.00	358.00	464.92	442.12	475.45	477.03	486.90
Mean weight (g)	150.00	1066.67	1833.85	1615.29	1998.64	1910.00	2069.31
% Immature	100.0	50.0	7.7	17.6	4.5	3.0	3.4
Mean age (years)	2.00	6.67	9.69	8.94	10.59	10.94	10.97
Age	Frequency (%)						
2	100.00	33.33					
3				5.88			
4			7.69	5.88	4.55	3.03	
5		33.33		5.88	4.55	3.03	6.90
6			15.38	11.76	9.09	6.06	3.45
7				5.88	4.55		6.90
8			7.69		4.55	6.06	10.34
9			15.38	5.88	4.55	9.09	6.90
10			7.69	29.41	13.64	15.15	6.90
11			23.08	5.88	13.64	6.06	3.45
12		16.67		5.88	9.09	15.15	13.79
13			7.69	17.65	18.18	18.18	13.79
14		16.67	15.38		4.55	12.12	17.24
15						3.03	10.34
16					4.55	3.03	
17							
18							
19					4.55		

* the total effort was 625 yds for each mesh

Appendix B10. Mesh size effects on walleye catches in the west basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	35	85	211	220	71	2	7
CUE* (number/100 yds/16 hrs)	5.0	12.14	30.14	31.43	10.14	0.29	1.00
CUE* (kg/100 yds/16 hrs)	2.19	7.00	22.89	26.15	10.25	0.24	0.92
Mean length (mm)	309.46	366.48	405.71	420.62	450.03	408.00	429.40
Mean weight (g)	438.33	576.13	759.38	832.07	1010.67	830.00	916.00
% Immature	54.2	45.2	21.6	16.1	0.0	0.0	0.0
Mean age (years)	6.25	7.03	9.46	10.07	11.27	12.00	12.00
Age	Frequency (%)						
2	37.50	3.23					
3							
4							
5	12.50	22.58	4.12	1.15			
6		12.90	6.19	6.90			
7		29.03	13.40	6.90			
8	16.67	6.45	10.31	10.34	6.67		
9	8.33	12.90	17.53	16.09	16.67		
10	12.50	9.68	9.28	14.94	20.00		40.00
11	4.17		29.90	21.84	26.67		20.00
12	4.17	3.23	4.12	9.20	10.00	100.00	20.00
13				2.30	3.33		
14	4.17		1.03	3.45			
15			2.06	5.75	10.00		
16							
17			1.03	1.15	3.33		20.00
18					3.33		
19							
20			1.03				

* the total effort was 700 yards for each mesh

Appendix B11. Mesh size effects on walleye catches in the east basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	96	169	339	209	63	5	3
CUE* (number/100 yds/16 hrs)	15.36	27.04	54.24	33.44	10.08	0.80	0.48
CUE* (kg/100 yds/16 hrs)	7.91	14.92	33.80	25.74	8.75	0.54	0.40
Mean length (mm)	339.41	357.90	379.69	409.48	426.77	381.50	424.00
Mean weight (g)	514.81	551.80	623.15	769.88	868.18	672.50	830.00
% Immature	51.9	48.6	31.5	12.8	4.5	25.0	0.0
Mean age (years)	7.15	7.36	8.34	10.10	11.14	8.50	10.5
Age	Frequency (%)						
0	7.41	1.45					
1							
2	3.70	1.45					
3							
4							
5	7.41	17.39	5.41			25.00	
6	3.70	15.94	9.91	3.49	4.76		
7	51.85	24.64	36.04	10.47	4.76	50.00	
8	3.70	13.04	16.22	15.12			
9		8.70	3.60	12.79	4.76		
10	3.70	4.35	5.41	18.60	23.81		50.00
11	14.81	7.25	16.22	23.26	33.33		50.00
12		4.35	1.80	3.49	9.52		
13			1.80	1.16			
14		1.45	0.90	5.81	9.52		
15	3.70		1.80	2.33	4.76	25.00	
16				1.16			
17			0.90	1.16	4.76		
18							
19							
20				1.16			
21							

* the total effort was 625 yards for each mesh

Appendix B12 Mesh size effects on walleye catches in Pipestone Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	17	30	76	63	37	5	1
CUE* (number/100 yds/16 hrs)	2.43	4.29	10.86	9.00	5.29	0.71	0.14
CUE* (kg/100 yds/16 hrs)	0.90	1.30	6.06	6.65	5.00	0.82	0.08
Mean length (mm)	290.76	276.07	363.18	399.11	436.05	437.20	370.00
Mean weight (g)	371.18	303.00	558.55	739.37	945.14	1152.00	560.00
% Immature	76.5	93.3	71.1	42.9	13.5	40.0	100.0
Mean age (years)	5.24	4.00	7.59	9.06	11.22	10.60	7.00
Age	Frequency (%)						
2	47.06	50.00					
3	11.76	13.33	1.32				
4			6.58				
5		13.33	14.47	1.59		20.00	
6	11.76	6.67	17.11	6.35			100.00
7		3.33	21.05	26.98	5.41		
8	5.88	6.67	14.47	20.63	5.41	20.00	
9			5.26	4.76	5.41		
10				3.17	5.41		
11	11.76	3.33	9.21	20.63	32.43		
12	5.88	3.33	3.95	11.11	37.84	20.00	
13	5.88		1.32		2.70	20.00	
14			1.32				
15			3.95	4.76	2.70	20.00	
16							
17							
18					2.70		
19							

* the total effort was 700 yards for each mesh

Appendix B13. Mesh size effects on walleye catches in Walker Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	10	14	41	19	21	7	2
CUE* (number/100 yds/16 hrs)	1.6	2.24	6.56	3.04	3.36	1.12	0.32
CUE* (kg/100 yds/16 hrs)	0.93	1.30	5.25	2.77	4.03	1.64	0.53
Mean length (mm)	358.00	356.21	407.29	428.79	473.76	501.14	532.00
Mean weight (g)	581.00	580.00	800.00	910.00	1200.48	1464.29	1655.00
% Immature	70.00	78.6	46.3	31.6	14.3	0.0	0.0
Mean age (years)	7.00	8.00	9.22	9.84	11.05	12.17	19.00
Age	Frequency (%)						
3		7.14					
4	30.00	7.14					
5			2.44				
6			4.88	5.26			
7	30.00	35.71	12.20	10.53			
8	10.00	35.71	24.39	5.26	9.52		
9	10.00		17.07	31.58	4.76		
10	20.00		7.32	5.26	4.76		
11		7.14	21.95	31.58	61.90	33.33	
12			4.88		4.76	50.00	
13			2.44		4.76		
14				5.26	4.76		50.00
15				5.26	4.76	16.67	
16							
17			2.44				
18							
19		7.14					
20							
21							
22							
23							
24							50.00

* the total effort was 625 yards for each mesh

Appendix B14. Mesh size effects on pike catches in the west basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	35	61	123	31	10	4	1
CUE* (number/100 yds/16 hrs)	5.00	8.71	17.57	4.43	1.43	0.57	0.14
CUE* (kg/100 yds/16 hrs)	4.75	7.91	18.01	5.82	3.09	0.54	0.09
Mean length (mm)	515.85	500.28	529.67	577.39	649.89	524.25	466.00
Mean weight (g)	950.00	908.17	1024.80	1313.55	2165.56	945.00	660.00
% Immature	9.1	15.0	5.7	0.0	0.0	0.0	0.0
Mean age (years)	6.21	5.35	5.84	6.94	7.44	5.75	5.00
Age	Frequency (%)						
2	3.03						
3	3.03	10.00	2.44				
4	15.15	21.67	11.38		11.11	25.00	
5	21.21	30.00	29.27	19.35			100.00
6	18.18	18.33	32.52	32.26	11.11	50.00	
7	15.15	10.00	14.63	19.35	55.56	25.00	
8	15.15	6.67	4.07	9.68			
9	3.03	1.67	3.25	9.68			
10			1.63	6.45			
11	3.03		0.81		22.22		
12		1.67		3.23			
13							
14	3.03						

* the total effort was 700 yards for each mesh

Appendix B15. Mesh size effects on pike catches in the east basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	25	43	75	11	4	3	2
CUE* (number/100 yds/16 hrs)	4.00	6.88	12.00	1.76	0.64	0.48	0.32
CUE* (kg/100 yds/16 hrs)	2.89	4.85	11.03	2.00	0.92	0.49	0.24
Mean length (mm)	446.80	469.02	519.65	557.91	555.25	545.67	497.00
Mean weight (g)	722.80	704.88	918.93	1134.55	1432.50	1026.67	755.00
% Immature	32.0	11.6	2.7	0.0	0.0	0.0	0.0
Mean age (years)	4.20	4.33	5.11	6.36	6.75	6.00	4.50
Age	Frequency (%)						
1	12.00						
2		2.33					
3	20.00	23.26	2.67				
4	36.00	37.21	36.00		25.00		50.00
5	20.00	20.93	38.67	45.45	25.00	66.67	50.00
6	4.00	11.63	10.67	18.18			
7		2.33	5.33	9.09			
8		2.33	2.67	18.18	25.00	33.33	
9	4.00		1.33				
10			1.33	9.09	25.00		
11	4.00						
12							
13			1.33				

* the total effort was 625 yards for each mesh

Appendix B16. Mesh size effects on pike catches in Pipestone Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	14	27	52	16	8	4	5
CUE* (number/100 yds/16 hrs)	2.00	3.86	7.43	2.29	1.14	0.57	0.71
CUE* (kg/100 yds/16 hrs)	1.67	3.33	7.87	4.32	3.25	1.98	1.90
Mean length (mm)	485.29	479.44	531.13	620.81	666.63	725.50	676.40
Mean weight (g)	832.86	862.96	1059.81	1891.25	2840.00	3462.50	2666.00
% Immature	7.1	3.7	0.0	0.0	12.5	0.0	0.0
Mean age (years)	4.64	4.70	5.88	7.38	8.50	9.50	8.20
Age	Frequency (%)						
2	14.29	11.11			12.50		
3	7.14	18.52					20.00
4	21.43	14.81	21.15				
5	28.57	18.52	30.77	6.25		25.00	
6	14.29	25.93	26.93	37.50			20.00
7	14.29	7.41	7.69	25.00	37.50		20.00
8			5.77	6 25	12.50		20.00
9		3.70	1.92	18.75	12.50		
10			1.92		12.50	50.00	
11			1.92				
12						25.00	20.00
13				6.25			
14							
15			1.92				
16					12.50		
17							

* the total effort was 700 yards for each mesh.

Appendix B17. Mesh size effects on pike catches in Walker Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	44	79	152	85	48	7	5
CUE* (number/100 yds/16hrs)	7.04	12.64	24.32	13.60	7.68	1.12	0.80
CUE* (kg/100 yds/16hrs)	11.04	15.51	31.56	21.71	14.94	2.54	2.51
Mean length (mm)	601.93	558.27	578.60	622.41	660.72	703.00	757.00
Mean weight (g)	1568.89	1227.45	1297.50	1596.47	1945.86	2267.50	3132.50
% Immature	7.4	9.8	3.3	0.0	0.0	0.0	0.0
Mean age (years)	8.07	6.75	7.04	7.98	8.79	10.25	11.75
Age	Frequency (%)						
2		3.92					
3	3.70	3.92					
4	3.70	5.88	7.61				
5	7.41	11.76	14.13	3.92			
6	11.11	13.73	23.91	17.65	3.45		
7	18.52	23.53	16.30	9.80	17.24		
8	14.81	17.65	16.30	31.37	27.59		
9	11.11	11.76	11.96	25.49	13.79	25.00	
10	7.41	7.84	3.26	7.84	27.59	25.00	25.00
11	14.81		3.26	1.96	6.90	50.00	25.00
12	3.70		3.26	1.96	3.45		25.00
13	3.70						
14							25.00

* the total effort was 625 yards for each mesh

Appendix B18 Mesh size effects on cisco catches in the Whiskey Jack basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	44	111	74	62	31	7	4
CUE* (number/100 yds/16 hrs)	29.33	74.00	49.33	41.33	20.67	4.67	2.67
CUE* (kg/100 yds/16 hrs)	8.83	24.97	24.45	23.89	12.53	3.06	1.65
Mean length (mm)	245.23	266.57	314.31	331.84	338.59	338.17	337.00
Mean weight (g)	300.91	337.45	495.64	578.00	606.47	656.67	617.50
% Immature	54.5	49.0	17.9	0.0	0.0	0.0	0.0
Mean age (years)	3.82	4.18	6.08	7.44	7.53	8.00	7.25
Age	Frequency (%)						
1	31.82						
2	18.18	35.29					
3		9.80	12.82				
4	13.64	15.69	17.95	8.00			
5	9.09	15.69	23.08	16.00	23.53	33.33	50.00
6	9.09	5.88	7.69	20.00	11.76		25.00
7	9.09	7.84	12.82	16.00	17.65		
8		5.88	7.69	4.00	11.76	16.67	
9	4.55		10.26	16.00	17.65	16.67	
10		3.92		8.00	5.88	16.67	
11			2.56	4.00	11.76	16.67	
12	4.55		2.56	4.00			
13			2.56	4.00			25.00

* the total effort was 150 yards for each mesh.

Appendix B19. Mesh size effects on cisco catches in the middle basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	57	186	91	87	69	61	50
CUE* (number/100 yds/16 hrs)	20.73	67.64	33.09	31.64	25.09	22.18	18.18
CUE* (kg/100 yds/16 hrs)	8.71	27.59	27.68	29.41	23.99	21.66	18.45
Mean length (mm)	261.77	266.30	359.91	372.55	378.39	377.79	382.57
Mean weight (g)	420.00	407.88	836.56	929.55	956.09	976.32	1015.00
% Immature	76.9	69.7	12.5	13.6	0.0	0.0	0.0
Mean age (years)	4.15	4.21	7.44	7.82	8.17	8.42	9.36
Age	Frequency (%)						
2	46.15	51.52	3.13				
3	30.77	18.18	9.38	9.09			
4			3.13	4.55			
5		6.06	15.63	13.64	17.39	10.53	
6			6.25	9.09	17.39	10.53	7.14
7		3.03	18.75		4.35	10.53	7.14
8		3.03	3.13	27.27	13.04	21.05	28.57
9	7.69	12.12	12.50	4.55	17.39	21.05	14.29
10	7.69		15.63	13.64	8.70	5.26	
11	7.69			13.64	13.04	15.79	28.57
12		3.03	6.25		8.70		14.29
13			6.25			5.26	
14		3.03					
15				4.55			

* the total effort was 275 yards for each mesh

Appendix B20 Mesh size effects on cisco catches in the east basin of Cross Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	108	185	215	149	133	105	102
CUE* (number/100 yds/16 hrs)	17.28	29.60	34.40	23.84	21.28	16.80	16.32
CUE* (kg/100 yds/16 hrs)	10.40	13.10	19.26	22.94	23.66	18.21	19.17
Mean length (mm)	294.38	272.30	292.75	363.00	382.13	381.34	392.44
Mean weight (g)	601.72	442.73	559.82	962.17	1112.00	1084.14	1174.69
% Immature	58.6	73.4	57.9	10.9	5.0	0.0	0.0
Mean age (years)	4.34	3.47	4.20	6.37	7.05	7.00	8.00
Age	Frequency (%)						
1			1.79				
2	55.17	71.88	55.36	4.35			
3	6.90	6.25	8.93	17.39	12.82	7.14	
4			1.79	8.70	2.56	10.71	6.25
5	3.45	1.56	7.14	8.70	7.69	7.14	3.13
6	3.45			6.52	15.38	14.29	6.25
7	6.90	4.69		10.87	17.95	14.29	18.75
8	13.79	7.81	7.14	28.26	20.51	28.57	31.25
9	3.45	4.69	5.36	4.35	5.13	3.57	18.75
10	3.45	1.56	7.14	6.52	7.69	7.14	6.25
11			3.57	2.17	10.26	3.57	6.25
12	3.45		1.79			3.57	
13				2.17			3.13
14							
15		1.56					

* the total effort was 625 yards for each mesh.

Appendix B21. Mesh size effects on cisco catches in Pipestone Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3	4.25	5.0	5.25
Number caught	2	4	24	18	16	3	6
CUE* (number/100 yds/16 hrs)	0.29	0.57	3.43	2.57	2.29	0.43	0.86
CUE* (kg/100 yds/16 hrs)	0.25	0.52	2.32	1.61	1.72	0.39	0.89
Mean length (mm)	364.00	366.00	346.13	342.11	354.56	380.33	391.33
Mean weight (g)	885.00	910.00	677.08	624.44	750.63	900.00	1040.00
% Immature	0.0	0.0	12.5	27.8	12.5	0.0	0.0
Mean age (years)	6.50	8.50	7.79	7.56	8.81	9.67	10.00
Age	Frequency (%)						
3					6.25		
4			4.17				
5			8.33	5.56			
6	50.00	25.00	20.83	38.89	18.75	33.33	16.67
7	50.00		12.50	5.56	6.25		
8			29.17	22.22	25.00		
9		50.00	4.17	22.22	31.25		16.67
10		25.00	8.33		6.25	33.33	16.67
11			8.33				33.33
12					6.25		
13						33.33	16.67
14				5.56			
15			4.17				

* the total effort was 700 yards for each mesh.

Appendix B22. Mesh size effects on cisco catches in Walker Lake, 1981.

	Mesh size (inches)						
	1.5	2.0	3.0	3.75	4.25	5.0	5.25
Number caught	62	155	97	4	1	1	0
CUE* (number/100 yds/16 hrs)	9.92	24.80	15.52	0.64	0.16	0.16	
CUE* (kg/100 yds/16 hrs)	1.10	4.82	4.46	0.19	0.05	0.14	
Mean length (mm)	186.60	230.23	265.19	278.67	284.00	364.00	
Mean weight (g)	110.61	194.52	287.28	303.33	300.00	860.00	
% Immature	80.7	32.6	2.5	0.0	0.0	100.0	
Mean age (years)	2.25	3.52	5.22	8.00	8.00	12.00	
Age	Frequency (%)						
1	7.02						
2	71.93	28.15					
3	14.04	30.37	2.47				
4	3.51	14.07	20.99				
5	3.51	20.00	46.91				
6		5.19	12.35				
7		1.48	8.64	33.33			
8			2.47	33.33	100.00		
9		0.74	2.47	33.33			
10							
11							
12						100.00	

* the total effort was 625 yards for each mesh.

Appendix B23. Age-specific mean lengths, weights and condition factors for whitefish from the west basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
1						1	1.39	156.00	60.00	1.58	1	0.71	156.00	60.00	1.58
2	13	19.40	213.31	130.77	1.33	10	13.89	218.50	144.00	1.33	23	16.43	215.57	136.52	1.33
3	4	5.97	321.00	482.50	1.46	6	8.33	335.17	571.67	1.50	10	7.14	329.50	536.00	1.48
4	1	1.49	364.00	800.00	1.66	2	2.78	336.00	570.00	1.48	3	2.14	345.33	646.67	1.54
5	2	2.99	396.00	990.00	1.60	3	4.17	417.67	1173.33	1.61	5	3.57	409.00	1100.00	1.60
6	4	5.97	435.50	1327.50	1.61	4	5.56	425.75	1315.00	1.69	8	5.71	430.63	1321.25	1.65
7	12	17.91	447.58	1458.33	1.62	7	9.72	443.00	1601.43	1.85	19	13.57	445.89	1511.05	1.70
8	5	7.46	447.80	1480.00	1.65	7	9.72	460.71	1674.29	1.71	12	8.57	455.33	1593.33	1.69
9	10	14.93	459.40	1529.00	1.57	6	8.33	474.17	1736.67	1.62	16	11.43	464.94	1606.88	1.59
10	3	4.48	482.33	1683.33	1.49	4	5.56	500.50	2047.50	1.63	7	5.00	492.71	1891.43	1.57
11	3	4.48	496.00	1940.00	1.60	8	11.11	504.13	2177.50	1.70	11	7.86	501.91	2112.73	1.67
12	6	8.96	490.67	2021.67	1.71	3	4.17	473.00	1803.33	1.70	10	7.14	489.50	1999.00	1.70
13						4	5.56	508.50	2422.50	1.84	4	2.86	508.50	2422.50	1.84
14	2	2.99	488.00	1945.00	1.68	4	5.56	522.00	2382.50	1.68	6	4.29	510.67	2236.67	1.68
15	1	1.49	499.00	2110.00	1.70	2	2.78	536.50	2655.00	1.70	3	2.14	524.00	2473.33	1.70
16						1	1.39	534.00	2660.00	1.75	1	0.71	534.00	2660.00	1.75
17															
18															
19	1	1.49	520.00	2350.00	1.67						1	0.71	520.00	2350.00	1.67

Appendix B24. Age-specific mean lengths, weights and condition factors for whitefish from the east basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	11	13.75	278.27	340.91	1.58	5	6.67	267.80	316.00	1.63	16	10.32	275.00	333.13	1.59
3	14	17.50	368.79	856.43	1.71	13	17.33	362.00	832.31	1.75	27	17.42	365.52	844.81	1.72
4	1	1.25	405.00	1140.00	1.72	2	2.67	386.50	1020.00	1.77	3	1.94	392.67	1060.00	1.75
5						2	2.67	435.50	1390.00	1.67	2	1.29	435.50	1390.00	1.67
6	13	16.25	456.62	1690.77	1.78	6	8.00	455.83	1801.67	1.90	19	12.26	456.37	1725.79	1.82
7	22	27.50	470.59	1891.82	1.81	28	37.33	473.11	2083.21	1.97	50	32.26	472.00	1999.00	1.90
8	4	5.00	482.00	2012.50	1.81	3	4.00	499.00	2406.67	1.94	7	4.52	489.29	2181.43	1.86
9	6	7.50	485.33	2083.33	1.82	2	2.67	498.50	2315.00	1.87	8	5.16	488.63	2141.25	1.83
10	1	1.25	485.00	1940.00	1.70	2	2.67	531.00	2905.00	1.94	3	1.94	515.67	2583.33	1.86
11	6	7.50	507.17	2405.00	1.84	3	4.00	530.67	2830.00	1.90	9	5.81	515.00	2546.67	1.86
12	1	1.25	486.00	2120.00	1.85	4	5.33	509.25	2835.00	2.15	5	3.23	504.60	2692.00	2.09
13						3	4.00	526.67	2653.33	1.81	3	1.94	526.67	2653.33	1.81
14						2	2.67	548.50	2940.00	1.78	2	1.29	548.50	2940.00	1.78
15	1	1.25	508.00	2440.00	1.86						1	0.65	508.00	2440.00	1.86

Appendix B25. Age-specific mean lengths, weights and condition factors for whitefish from Pipestone Lake, 1981.

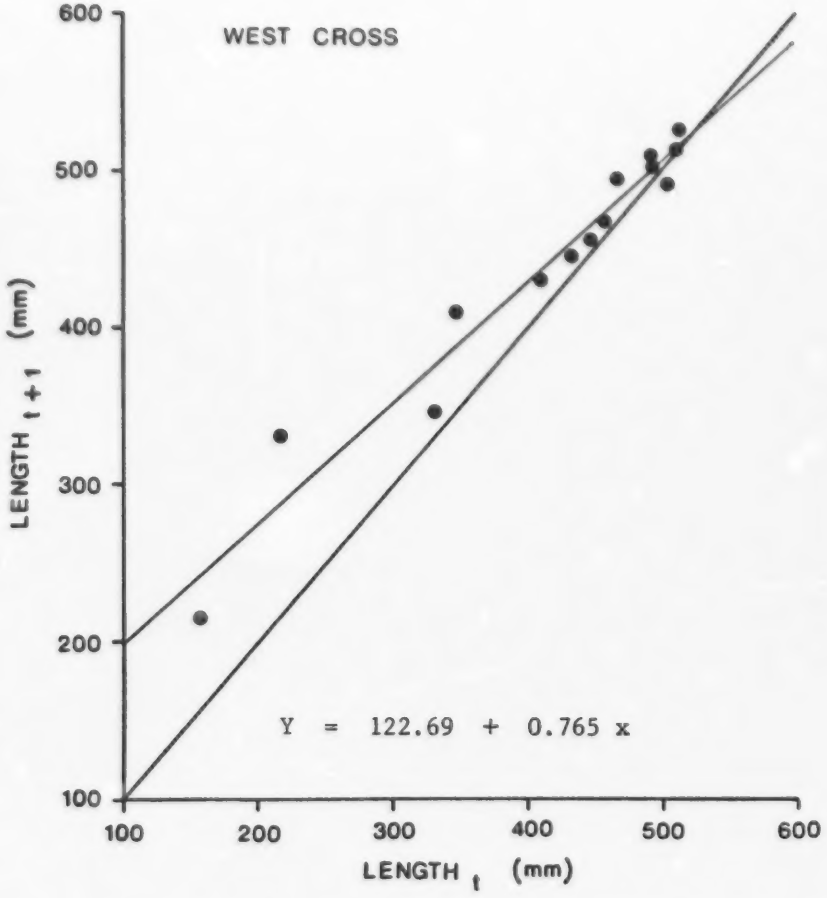
Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
3	1	7.14	300.00	430.00	1.59						1	2.78	300.00	430.00	1.59
4															
5															
6															
7	1	7.14	398.00	780.00	1.24						1	2.78	398.00	780.00	1.24
8	2	14.29	476.50	1705.00	1.56	2	9.09	462.50	1750.00	1.77	4	11.11	469.50	1727.50	1.67
9	2	14.29	460.50	1640.00	1.68						2	5.56	460.50	1640.00	1.68
10	1	7.14	503.00	2170.00	1.71	7	31.82	485.29	2031.43	1.77	8	22.22	487.50	2048.75	1.76
11	1	7.14	442.00	1400.00	1.62	3	13.64	496.00	2110.00	1.73	4	11.11	482.50	1932.50	1.70
12						6	27.27	497.83	2116.67	1.72	6	16.67	497.83	2116.67	1.72
13	2	14.29	494.00	2060.00	1.68	2	9.09	514.50	2580.00	1.88	4	11.11	504.25	2320.00	1.78
14	1	7.14	494.00	2250.00	1.87	2	9.09	521.00	2240.00	1.58	3	8.33	512.00	2243.33	1.67
15	2	14.29	506.00	2340.00	1.81						2	5.56	506.00	2340.00	1.81
16	1	7.14	502.00	2280.00	1.80						1	2.78	502.00	2280.00	1.80

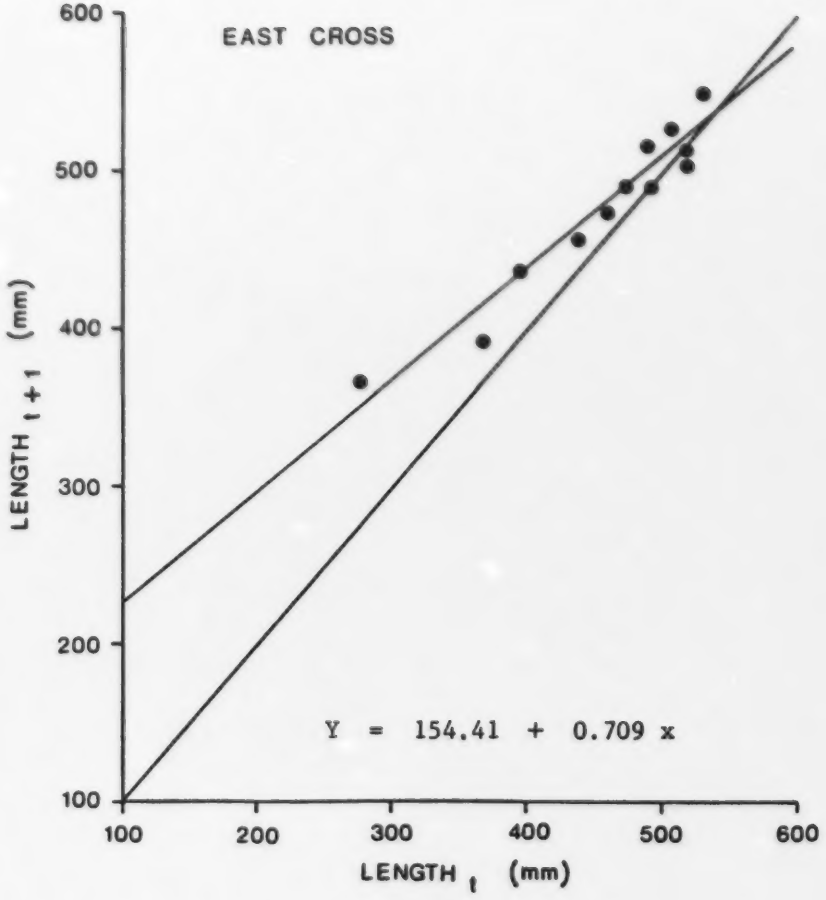
Appendix B26. Age-specific mean lengths, weights and condition factors for whitefish caught in experimental sets in Walker Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	2	2.82	210.00	125.00	1.31						3	2.48	212.67	133.33	1.36
3	1	1.41	276.00	300.00	1.43						1	0.83	276.00	300.00	1.43
4	3	4.23	362.67	783.33	1.61	1	2.08	324.00	560.00	1.65	4	3.31	353.00	727.50	1.62
5	3	4.23	352.67	706.67	1.61	4	8.33	373.50	815.00	1.55	7	5.79	364.57	768.57	1.57
6	4	5.63	420.00	1325.00	1.78	5	10.42	421.20	1274.00	1.70	9	7.44	420.67	1296.67	1.73
7	2	2.82	457.00	1525.00	1.59	2	4.17	449.00	1680.00	1.85	4	3.31	453.00	1602.50	1.72
8	1	1.41	480.00	1850.00	1.67	6	12.50	459.50	1650.00	1.69	7	5.79	462.43	1678.57	1.68
9	7	9.86	471.14	1835.71	1.73	1	2.08	496.00	2050.00	1.68	9	7.44	479.78	1911.11	1.71
10	11	15.49	469.64	1807.27	1.75	5	10.42	478.00	1960.00	1.79	16	13.44	472.25	1855.00	1.76
11	7	9.86	482.29	2012.86	1.79	3	6.25	498.00	2066.67	1.68	10	8.26	487.00	2029.00	1.76
12	7	9.86	482.86	1854.29	1.63	6	12.50	498.83	2188.33	1.76	13	10.74	490.23	2008.46	1.69
13	10	14.08	499.20	2310.00	1.85	8	16.67	520.25	2537.50	1.80	18	14.88	508.56	2411.11	1.82
14	8	11.27	503.25	2293.75	1.80	5	10.42	516.40	2562.00	1.86	13	10.74	508.31	2396.92	1.82
15	2	2.82	503.00	2375.00	1.86	2	4.17	538.00	2750.00	1.76	4	3.31	520.50	2562.50	1.81
16	2	2.84	513.00	2575.00	1.91						2	1.65	513.00	2575.00	1.91
17															
18															
19	1	1.41	548.00	2800.00	1.70						1	0.83	548.00	2800.00	1.70

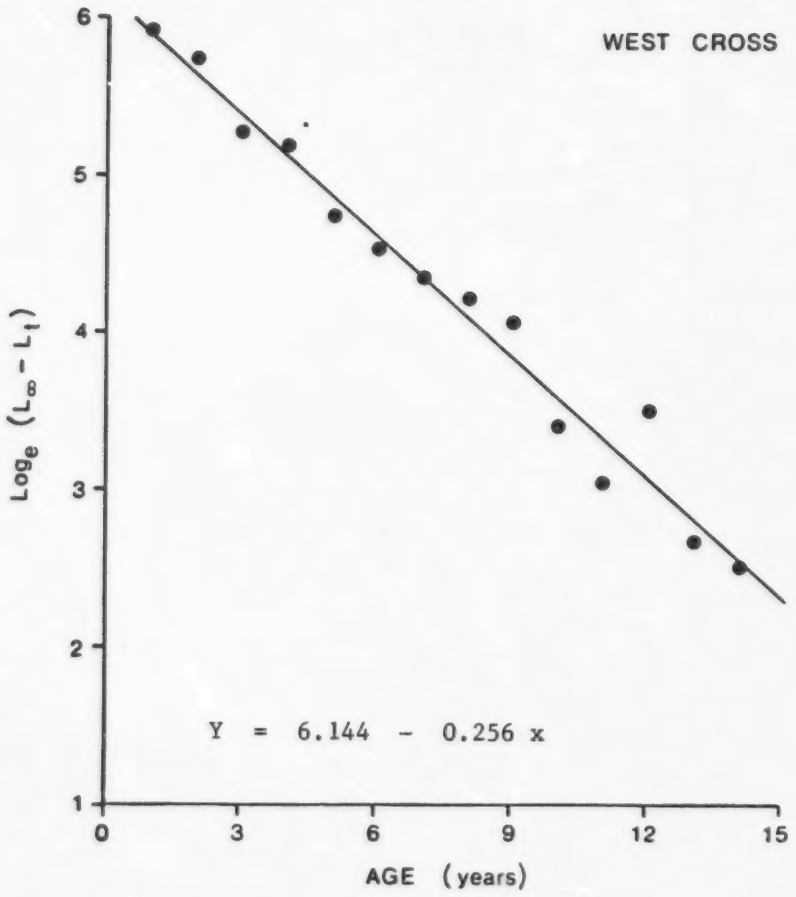
Appendix B27. Age-specific mean lengths, weights and condition factors for whitefish caught in commercial nets (4.25 inch mesh) in Walker Lake, 1981.

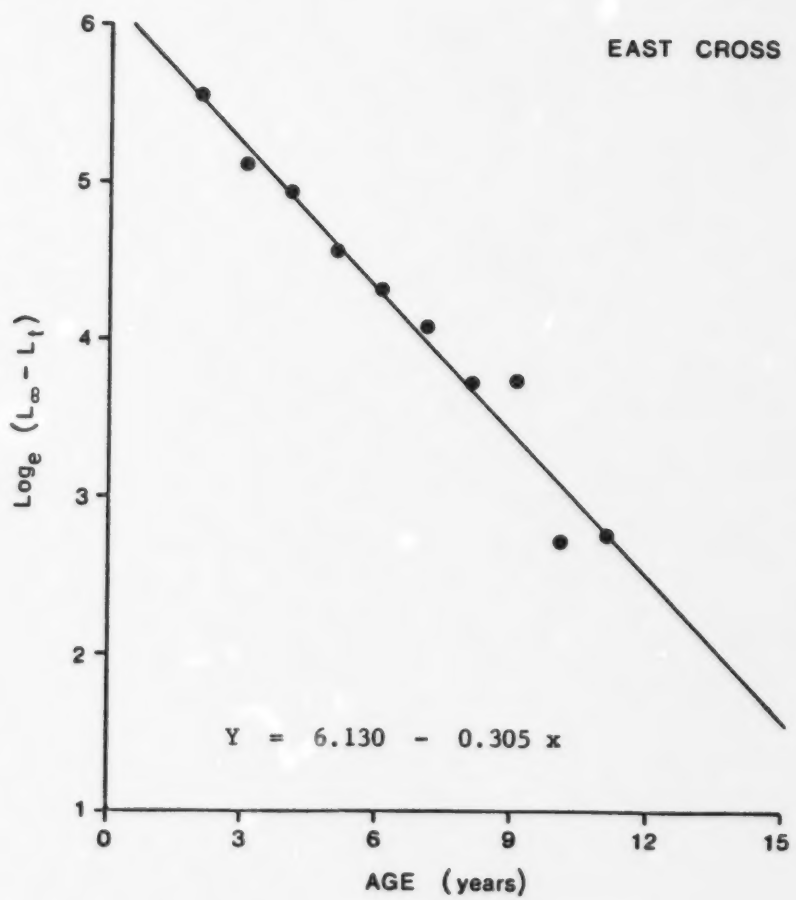
Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
3	4	4.94	334.50	655.00	1.75						4	2.31	334.50	655.00	1.75
4	3	3.70	360.33	766.67	1.63	5	5.49	351.60	718.00	1.64	8	4.62	354.88	736.25	1.63
5	13	16.05	382.54	970.77	1.72	12	13.19	388.17	1038.33	1.74	25	14.45	385.24	1003.20	1.73
6	19	23.46	424.84	1345.26	1.74	27	29.67	419.96	1291.48	1.73	46	26.59	421.98	1313.70	1.73
7	12	14.81	440.67	1545.83	1.80	11	12.09	445.82	1561.82	1.75	24	13.87	442.67	1553.33	1.78
8	8	9.88	470.13	1825.00	1.76	10	10.99	455.50	1753.00	1.84	18	10.40	462.00	1785.00	1.80
9	6	7.41	466.00	1818.33	1.80	7	7.69	479.71	1997.14	1.80	13	7.51	473.38	1914.62	1.80
10	4	4.94	475.00	1817.50	1.69	5	5.49	501.00	2154.00	1.71	9	5.20	489.44	2004.44	1.70
11	1	1.23	486.00	2000.00	1.74	5	5.49	495.20	2096.00	1.72	6	3.47	493.67	2080.00	1.72
12						3	3.30	495.33	2166.67	1.78	3	1.73	495.33	2166.67	1.78
13	5	6.17	478.40	1980.00	1.81	3	3.30	494.67	2013.33	1.65	8	4.62	484.50	1992.50	1.75
14	3	3.70	499.33	2333.33	1.85	3	3.30	527.33	2683.33	1.83	6	3.47	513.33	2508.33	1.84
15	1	1.23	500.00	2100.00	1.68						1	0.58	500.00	2100.00	1.68
16															
17															
18	1	1.23	556.00	3350.00	1.95						1	0.58	556.00	3350.00	1.95
19	1	1.23	534.00	2840.00	1.87						1	0.58	534.00	2840.00	1.87



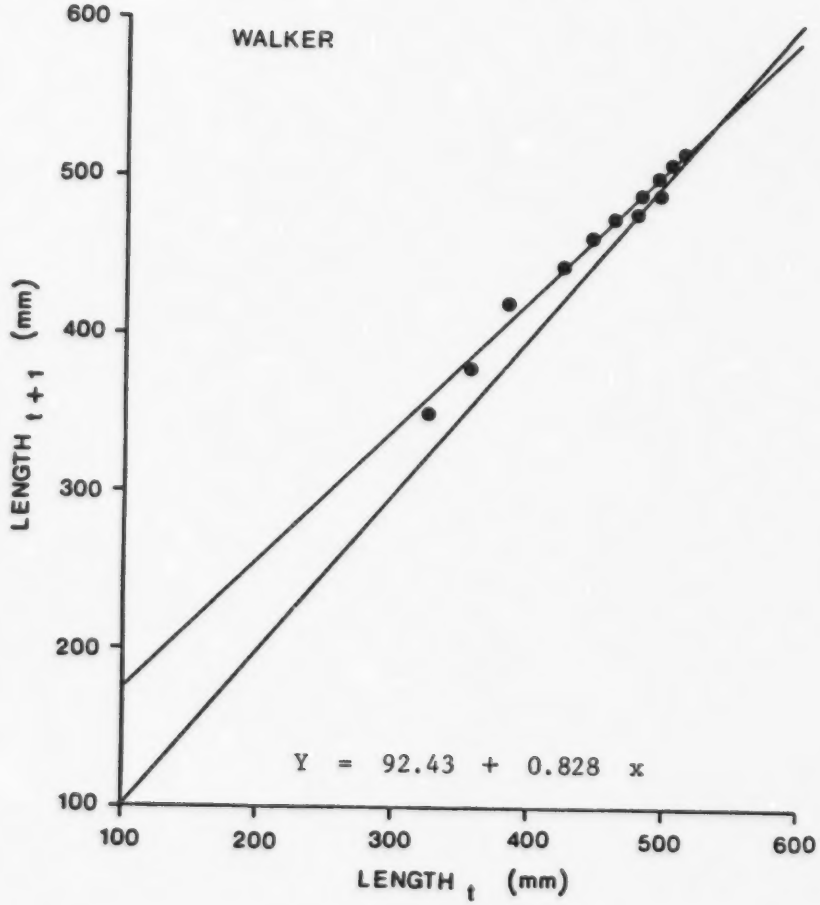


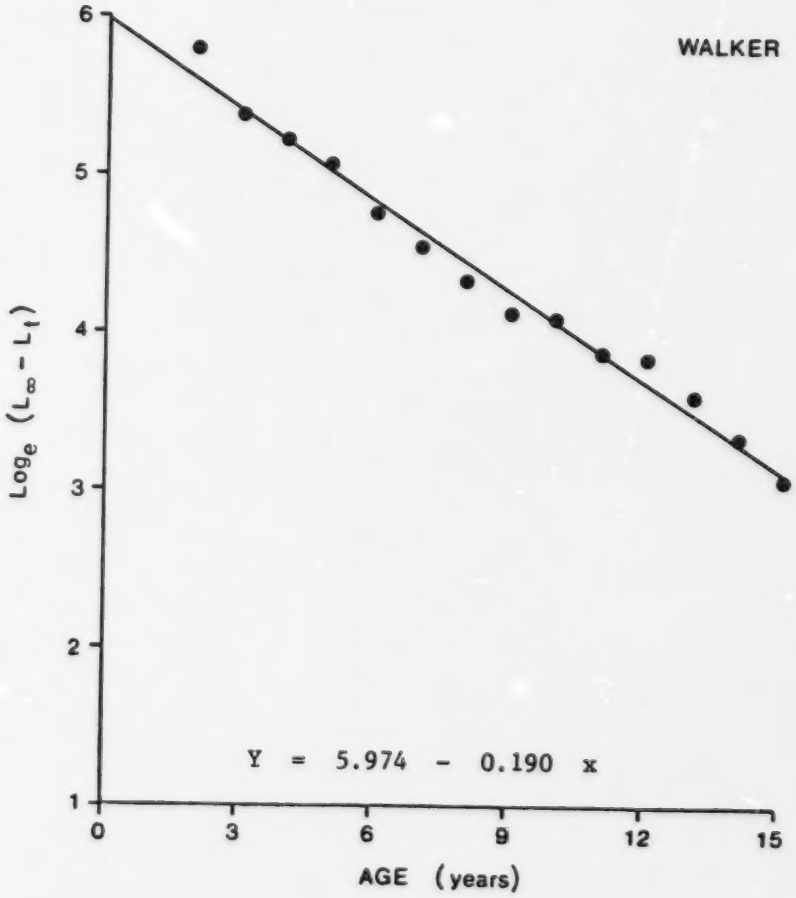
Appendix B28. Walford plots for whitefish from the west and east basins of Cross Lake, 1981.





Appendix B29. Brody plots for whitefish from the west and east basins of Cross Lake, 1981.





Appendix B30. Walford and Brody plots for whitefish from Walker Lake, 1981.

Appendix B31 . Maturity schedules for whitefish, 1981.

Age .	West Cross				East Cross				Pipestone				Walker			
	Males		Females		Males		Females		Males		Females		Males		Females	
	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.
1			1													
2	13		10		11		5						2			
3	4		6		13	1	13		1				5			
4	2	1	2		1		2						3	3	6	
5			3				2						9	7	6	10
6		4	1	3		13	1	5					1	22	5	27
7		12		7		22	2	26		1				14		13
8		5		7		4		3	1	1		2		9		16
≤9		26		32		15		16		10		20		77		56

Appendix B32. Age-specific mean lengths, weights and condition factors for walleye from the west basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	3	2.88	182.67	66.67	1.09	7	4.09	180.57	62.86	1.06	10	3.64	181.20	64.00	1.07
3															
4															
5	8	7.69	325.63	375.00	1.09	7	4.09	329.29	388.57	1.09	15	5.45	327.33	381.33	1.09
6	6	5.77	348.83	460.00	1.07	10	5.85	361.00	528.00	1.10	16	5.82	356.44	502.50	1.09
7	11	10.58	368.18	562.73	1.12	17	9.94	386.53	653.53	1.12	28	10.18	379.32	617.86	1.12
8	10	9.62	378.50	603.00	1.11	17	9.94	404.88	753.53	1.13	27	9.82	395.11	697.78	1.12
9	12	11.54	385.25	665.83	1.15	30	17.54	416.33	815.33	1.12	42	15.27	407.45	772.62	1.13
10	11	10.58	423.91	845.45	1.10	25	14.62	427.76	854.00	1.09	36	13.09	426.58	851.39	1.09
11	17	16.35	419.53	824.71	1.11	41	23.98	445.73	970.00	1.09	58	21.09	438.05	927.41	1.09
12	11	10.58	415.18	797.27	1.11	8	4.68	451.25	1021.25	1.11	19	6.91	430.37	891.58	1.11
13	3	2.88	438.67	920.00	1.09						3	1.09	438.67	920.00	1.09
14	2	1.92	451.00	1020.00	1.11	3	1.75	490.33	1240.00	1.05	5	1.82	474.60	1152.00	1.07
15	5	4.81	435.80	954.00	1.15	5	2.92	478.40	1208.00	1.10	10	3.64	457.10	1081.00	1.12
16															
17	3	2.88	436.67	940.00	1.12	1	0.58	518.00	1440.00	1.04	4	1.45	457.00	1065.00	1.10
18	1	0.96	466.00	1060.00	1.05						1	0.36	466.00	1060.00	1.05
19															
20	1	0.96	470.00	1140.00	1.10						1	0.36	470.00	1140.00	1.10

Appendix B33. Age-specific mean lengths, weights and condition factors for walleye from the east basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
0											3	0.94	77.33	10.00	2.16
1															
2						2	1.14	202.00	105.00	1.27	2	0.63	202.00	105.00	1.27
3															
4															
5	10	7.04	324.00	405.00	1.18	11	6.29	326.36	396.36	1.14	21	6.56	325.24	400.48	1.16
6	16	11.27	336.69	438.13	1.15	11	6.29	357.82	525.45	1.13	27	8.44	345.30	473.70	1.14
7	43	30.28	355.93	516.98	1.14	40	22.86	369.10	569.90	1.13	83	25.94	362.28	542.48	1.14
8	13	9.15	373.54	600.77	1.15	28	16.00	388.25	668.57	1.14	41	12.81	383.59	647.07	1.14
9	10	7.04	393.30	668.00	1.09	12	6.86	401.08	717.50	1.11	22	6.88	397.55	695.00	1.10
10	15	10.56	399.40	713.33	1.12	17	9.71	426.12	836.47	1.08	32	10.00	413.59	778.75	1.10
11	13	9.15	403.15	733.85	1.12	42	24.00	429.31	863.81	1.09	55	17.19	423.13	833.09	1.10
12	6	4.23	407.33	773.33	1.15	4	2.29	429.00	840.00	1.07	10	3.13	416.00	800.00	1.11
13	1	0.70	417.00	790.00	1.09	2	1.14	431.00	845.00	1.05	3	0.94	426.33	826.67	1.06
14	6	4.23	435.83	890.00	1.07	3	1.71	445.00	990.00	1.13	9	2.81	438.89	923.33	1.09
15	4	2.82	421.25	875.00	1.17	3	1.71	471.00	1163.33	1.11	7	2.19	442.57	998.57	1.14
16															
17	1	0.70	440.00	970.00	1.14						1	0.31	440.00	970.00	1.14
18	3	2.11	447.00	1016.67	1.14						3	0.94	447.00	1016.67	1.14
19															
20															
21	1	0.70	430.00	1000.00	1.26						1	0.31	430.00	1000.00	1.26

Appendix B34 Age-specific mean lengths, weights and condition factors for walleye from Pipestone Lake, 1981.

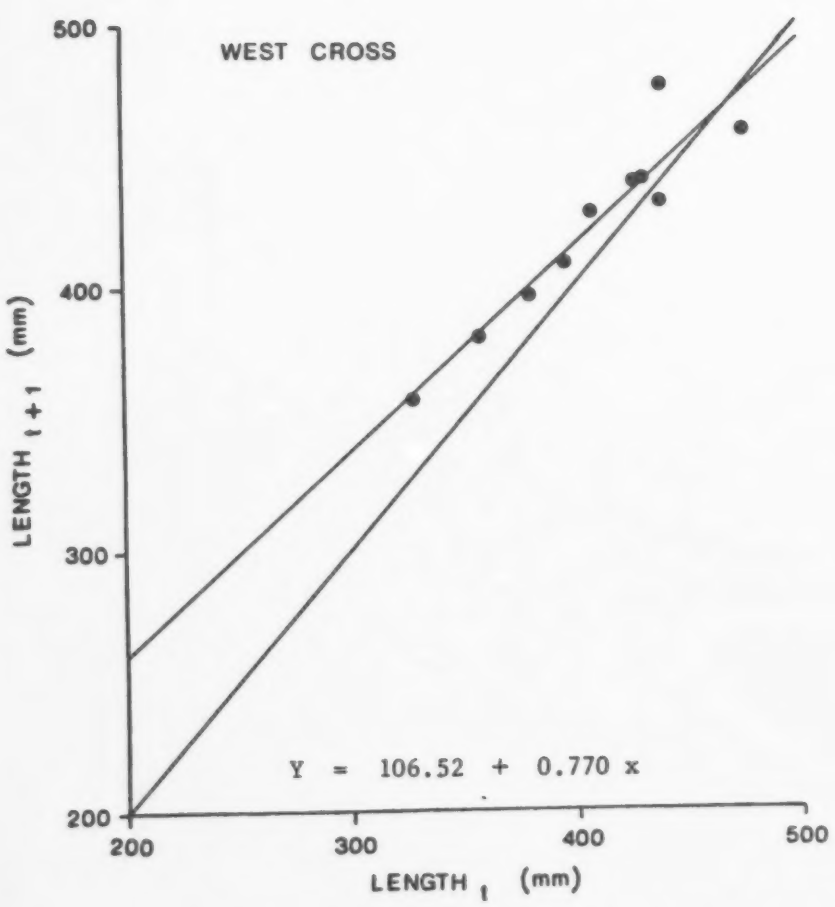
Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	9	10.59	211.56	114.44	1.20	14	9.72	214.14	122.86	1.25	23	10.04	213.13	119.57	1.23
3	3	3.53	253.33	186.67	1.15	4	2.78	250.50	182.50	1.12	7	3.06	251.71	184.29	1.13
4	3	3.53	313.67	350.00	1.13	2	1.39	306.00	325.00	1.14	5	2.18	310.00	340.00	1.13
5	10	11.76	323.20	366.00	1.08	7	4.86	336.14	437.14	1.13	17	7.42	328.00	395.29	1.10
6	7	8.24	352.43	510.00	1.16	14	9.72	355.21	520.71	1.16	21	9.17	354.29	517.14	1.16
7	7	8.24	350.71	512.86	1.16	30	20.83	385.73	666.00	1.15	37	16.16	379.11	637.03	1.15
8	10	11.76	367.60	584.00	1.16	20	13.89	391.70	710.50	1.18	30	13.10	383.67	668.33	1.17
9	3	3.53	367.33	576.67	1.16	6	4.17	395.17	723.33	1.16	9	3.93	385.89	674.44	1.16
10						4	2.78	421.75	845.00	1.12	4	1.75	421.75	845.00	1.12
11	12	14.12	400.42	720.00	1.12	23	15.97	431.70	921.30	1.13	35	15.28	420.97	852.29	1.13
12	12	14.12	411.67	804.17	1.15	15	10.42	450.53	1021.33	1.11	27	11.79	433.26	924.81	1.13
13	1	1.18	427.00	900.00	1.16	3	2.08	460.33	1103.33	1.10	4	1.75	452.00	1052.50	1.12
14	1	1.18	450.00	1000.00	1.10						1	0.44	450.00	1000.00	1.10
15	6	7.06	427.67	870.00	1.11	2	1.39	504.00	1510.00	1.14	8	3.49	446.75	1030.00	1.12
16															
17															
18															
19	1	1.18	458.00	1080.00	1.12						1	0.44	458.00	1080.00	1.12

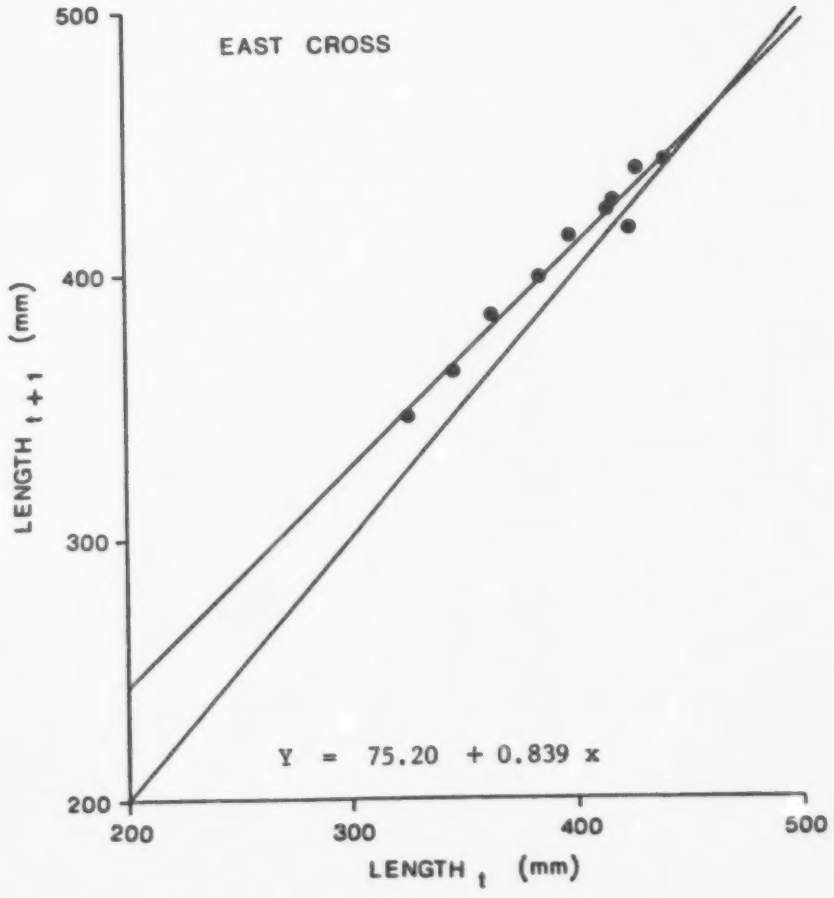
Appendix B35. Age-specific mean lengths, weights and condition factors for walleye caught in experimental sets in Walker Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
3	1	2.56	230.00	140.00	1.15						1	0.88	230.00	140.00	1.15
4	1	2.56	256.00	200.00	1.19	3	4.05	251.33	170.00	1.07	4	3.54	252.50	177.50	1.10
5						1	1.35	330.00	400.00	1.11	1	0.88	330.00	400.00	1.11
6						3	4.05	374.00	610.00	1.16	3	2.65	374.00	610.00	1.16
7	6	15.38	361.50	560.00	1.18	9	12.16	374.89	627.78	1.18	15	13.27	369.53	600.67	1.18
8	6	15.38	378.67	678.33	1.22	13	17.57	391.54	721.54	1.19	19	16.81	387.47	707.89	1.20
9	8	20.51	394.00	702.50	1.15	7	9.46	407.29	764.29	1.12	15	13.27	400.20	731.33	1.13
10	2	5.13	407.00	750.00	1.11	5	6.76	436.00	958.00	1.16	7	6.19	427.71	898.57	1.15
11	10	25.64	437.90	920.00	1.08	21	28.38	482.24	1262.38	1.11	31	27.43	467.94	1151.94	1.10
12	1	2.56	396.00	630.00	1.01	5	6.76	483.20	1310.00	1.13	6	5.31	468.67	1196.67	1.11
13	1	2.56	430.00	820.00	1.03	1	1.35	480.00	1120.00	1.01	2	1.77	455.00	970.00	1.02
14	1	2.56	496.00	1340.00	1.10	2	2.70	572.00	2045.00	1.09	3	2.65	546.67	1810.00	1.09
15						3	4.05	523.33	1663.33	1.12	3	2.65	523.33	1663.33	1.12
16															
17	1	2.56	412.00	830.00	1.19						1	0.88	412.00	830.00	1.19
18															
19						1	1.35	478.00	1230.00	1.13	1	0.88	478.00	1230.00	1.13
20															
21															
22															
23															
24	1	2.56	488.00	1200.00	1.03						1	0.88	488.00	1200.00	1.03

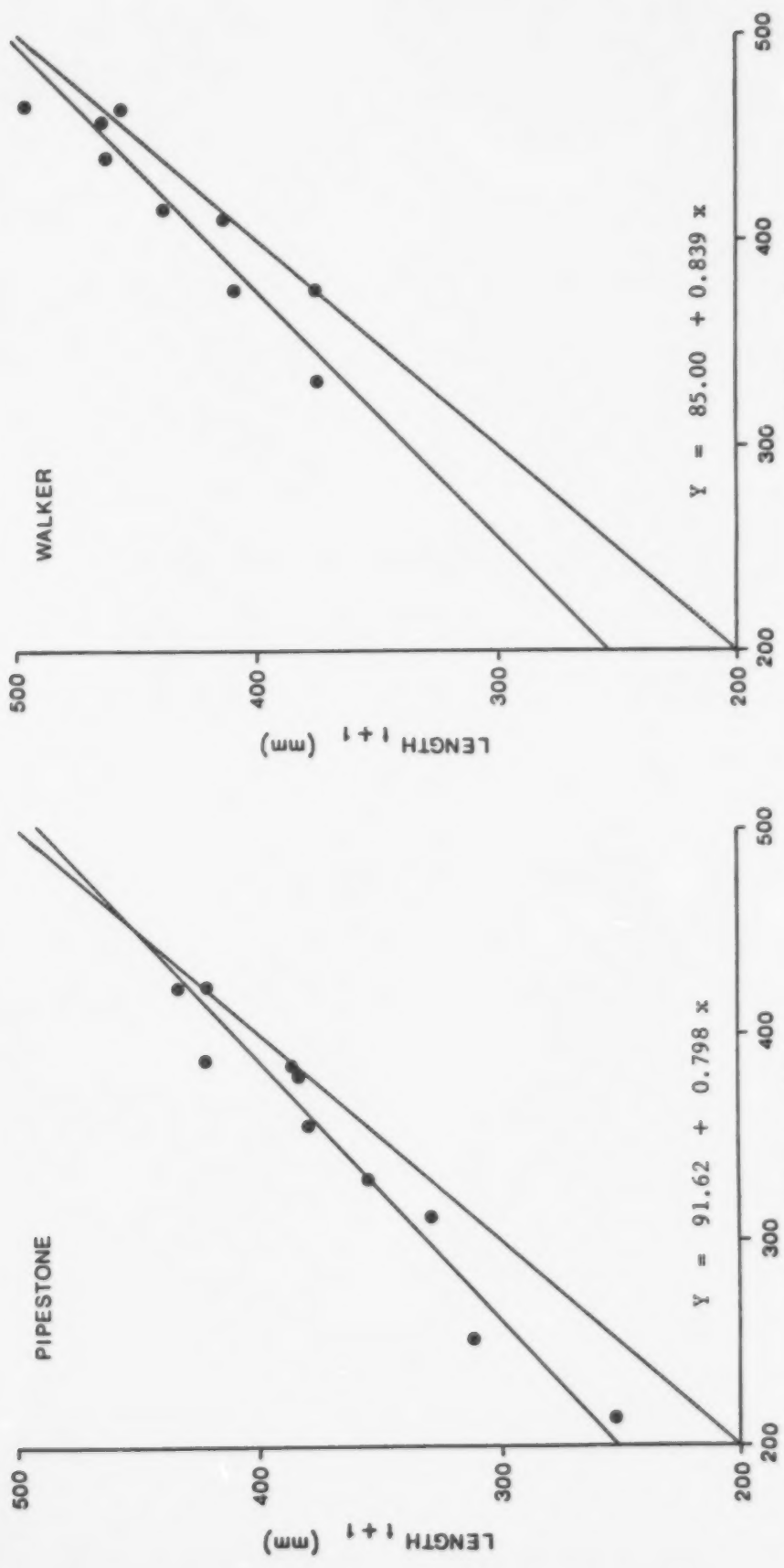
Appendix B36. Age-specific mean lengths, weights and condition factors for walleye caught in commercial nets (4.25 inch mesh) in Walker Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
7						5	3.31	388.00	720.00	1.22	5	2.27	388.00	720.00	1.22
8	10	14.49	412.30	795.00	1.13	26	17.22	421.69	857.69	1.13	36	16.36	419.22	840.28	1.13
9	8	11.59	393.25	693.75	1.14	27	17.88	425.70	859.26	1.11	35	15.91	418.29	821.43	1.12
10	6	8.70	439.00	891.67	1.06	22	14.57	440.91	936.36	1.09	28	12.73	440.50	926.79	1.08
11	33	47.83	444.67	934.85	1.06	54	35.76	468.15	1098.15	1.06	87	39.55	459.24	1036.21	1.06
12	3	4.35	440.00	966.67	1.13	4	2.65	447.00	975.00	1.09	7	3.18	444.00	971.43	1.11
13						4	2.65	467.50	1075.00	1.05	4	1.82	467.50	1075.00	1.05
14	3	4.35	445.33	900.00	1.02	2	1.32	493.00	1225.00	1.01	5	2.27	464.40	1030.00	1.01
15	4	5.80	446.00	962.50	1.08	3	1.99	462.00	1083.33	1.10	7	3.18	452.86	1014.29	1.09
16						2	1.32	547.00	1950.00	1.19	2	0.91	547.00	1950.00	1.19
17						1	0.66	554.00	1650.00	0.97	1	0.45	554.00	1650.00	0.97
18															
19															
20															
21	2	2.90	483.00	1150.00	1.03						2	0.91	483.00	1150.00	1.03
22						1	0.66	494.00	1150.00	0.95	1	0.45	494.00	1150.00	0.95

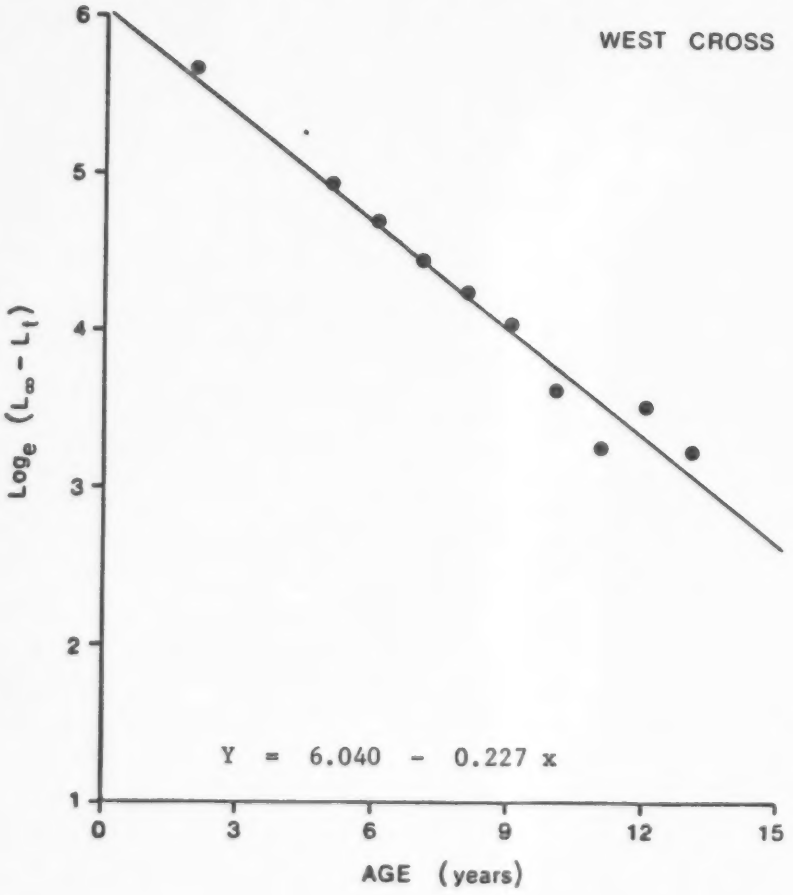


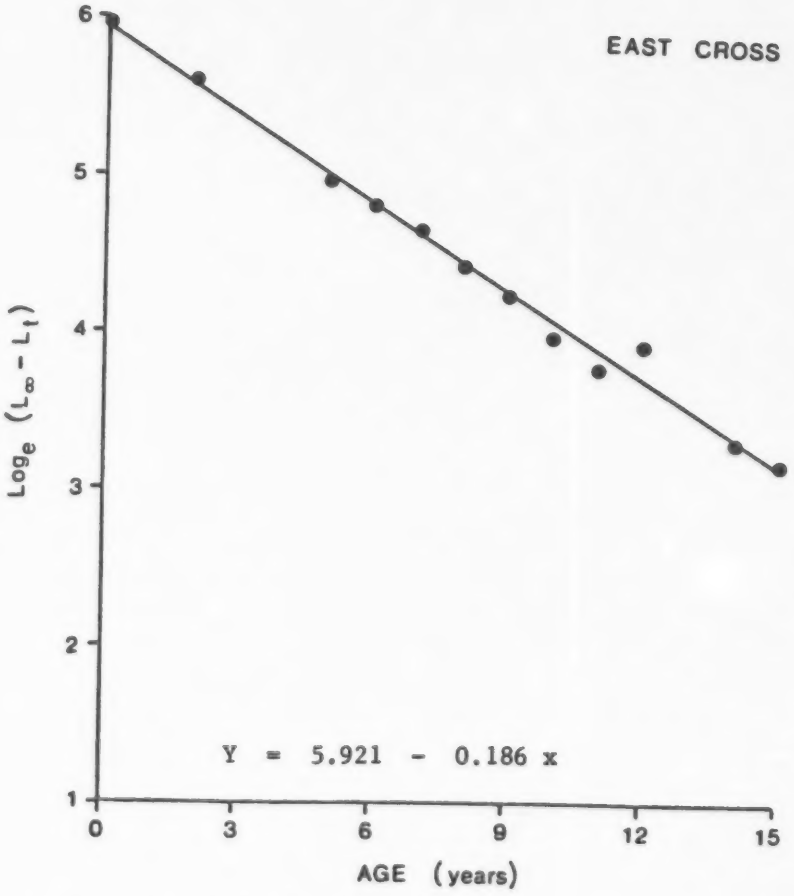


Appendix B37. Walford plots for walleye from the west and east basins of Cross Lake, 1981.

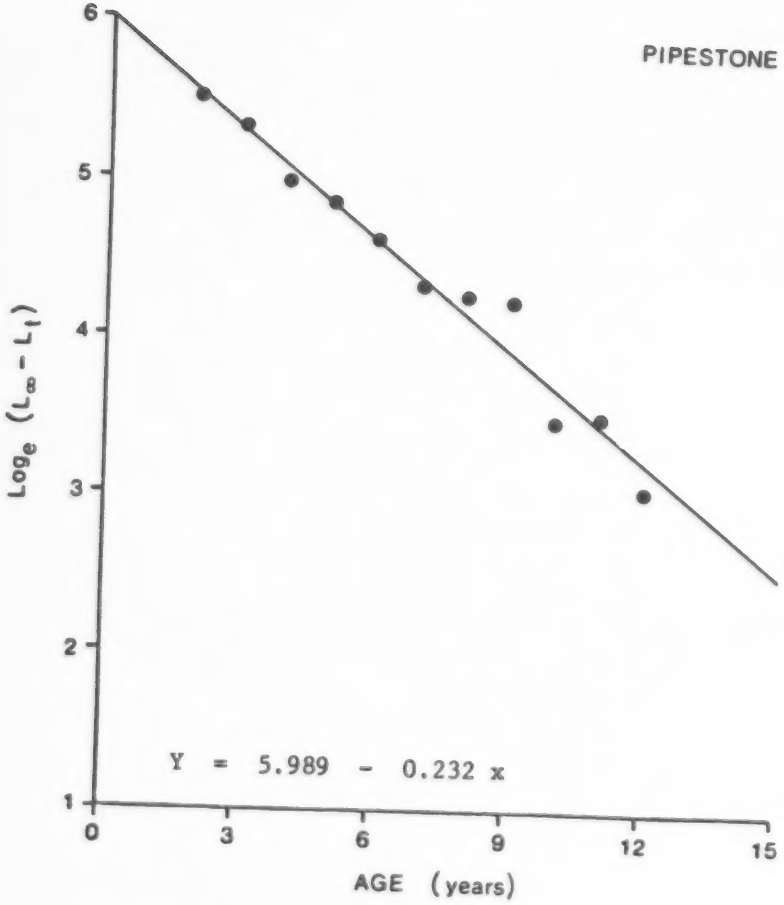


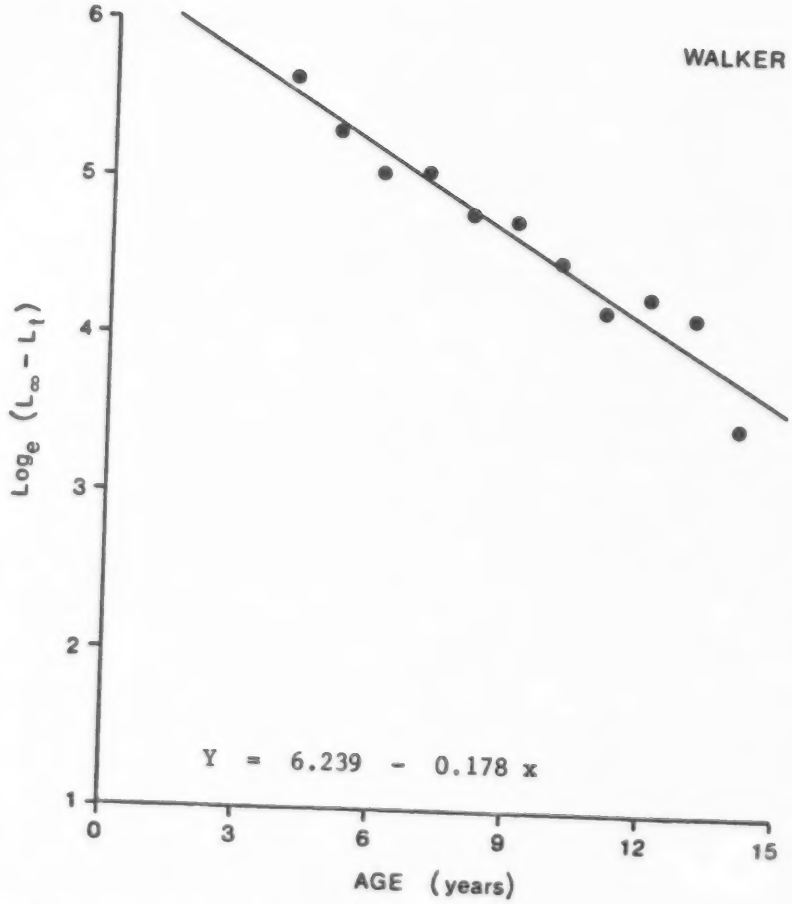
Appendix B38. Walford plots for walleye from Pipestone and Walker lakes, 1981





Appendix B39. Brody plots for walleye from the west and east basins of Cross Lake, 1981.





Appendix B40. Brody plots for walleye from Pipestone and Walker lakes, 1981.

Appendix B41. Maturity schedules for walleye, 1981.

Age	West Cross				East Cross				Pipestone				Walker			
	Males		Females		Males		Females		Males		Females		Males		Females	
	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.
≤4	3		7				2		15		20		2		3	
5	7	1	7		10		11		9	1	7				1	
6	6		9	1	10	6	9	2	5	2	14				3	
7	4	7	10	7	11	32	28	12	3	4	26	4	5	1	13	1
8	2	8	3	14		13	8	20	6	4	17	3	6	10	23	16
9		12	3	27		10	1	11		3	4	2	5	11	14	20
10		11		25	2	13		17				4		8	7	20
11		17		41		13		42	2	10	1	22		43	3	72
12	1	10		8	1	5		4		12	1	14		4		9
≥13		15		9		16		8		9		5		13		20

Appendix B42. Age-specific mean lengths, weights and condition factors for pike from the west basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2						1	0.58	338.00	260.00	0.67	1	0.38	338.00	260.00	0.67
3	1	1.11	358.00	300.00	0.65	9	5.26	389.56	412.22	0.65	10	3.83	386.40	401.00	0.65
4	13	14.44	473.08	725.38	0.68	21	12.28	477.29	704.76	0.64	34	13.03	475.68	712.65	0.65
5	29	32.22	495.07	821.07	0.67	39	22.81	520.51	908.46	0.64	68	26.05	509.66	871.19	0.65
6	24	26.67	518.08	956.25	0.68	46	26.90	545.61	1059.13	0.64	70	26.82	536.17	1023.86	0.66
7	11	12.22	544.36	1103.64	0.68	30	17.54	573.57	1287.67	0.65	41	15.71	565.73	1238.29	0.66
8	8	8.89	532.88	1011.25	0.66	9	5.26	577.78	1413.33	0.69	17	6.51	556.65	1224.12	0.68
9	2	2.22	581.00	1370.00	0.71	7	4.09	637.14	1715.71	0.65	9	3.45	624.67	1638.89	0.66
10	1	1.11	658.00	1870.00	0.66	3	1.75	664.67	2003.33	0.65	4	1.53	663.00	1970.00	0.65
11	1	1.11	528.00	1140.00	0.77	3	1.75	783.33	4120.00	0.82	4	1.53	719.50	3375.00	0.81
12						2	1.17	743.00	3665.00	0.83	2	0.77	743.00	3665.00	0.83
13															
14						1	0.58	640.00	2090.00	0.80	1	0.38	640.00	2090.00	0.80

Appendix B43. Age-specific mean lengths, weights and condition factors for pike from the east basin of Cross Lake, 1981.

	Males					Females					Both Sexes				
Age	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
1						3	2.75	207.33	76.67	0.86	3	1.84	207.33	76.67	0.86
2	1	1.89	292.00	190.00	0.76						1	0.61	292.00	190.00	0.76
3	10	18.89	385.30	417.00	0.72	7	6.42	374.43	337.14	0.63	17	10.43	380.82	384.12	0.68
4	21	39.62	464.57	648.57	0.65	33	30.28	480.24	668.79	0.60	54	33.13	474.15	660.93	0.62
5	10	18.87	489.70	776.00	0.66	41	37.61	524.63	886.59	0.61	52	31.90	517.15	862.12	0.62
6	5	9.43	545.00	992.00	0.61	11	10.09	558.73	1086.36	0.62	16	9.82	554.44	1056.88	0.62
7	3	5.66	534.33	973.33	0.63	3	2.75	599.67	1503.33	0.70	6	3.68	567.00	1238.33	0.67
8	2	3.77	540.50	945.00	0.59	5	4.59	606.00	1452.00	0.65	7	4.29	587.71	1307.14	0.63
9	1	1.89	720.00	2670.00	0.72	1	0.92	682.00	2000.00	0.63	2	1.23	701.00	2335.00	0.68
10						3	2.75	671.33	2133.33	0.70	3	1.84	671.33	2133.33	0.70
11						1	0.92	792.00	3600.00	0.72	1	0.61	792.00	3600.00	0.72
12															
13						1	0.92	822.00	4470.00	0.80	1	0.61	822.00	4470.00	0.80

Appendix B44. Age-specific mean lengths, weights and condition factors for pike from Pipestone Lake, 1981.

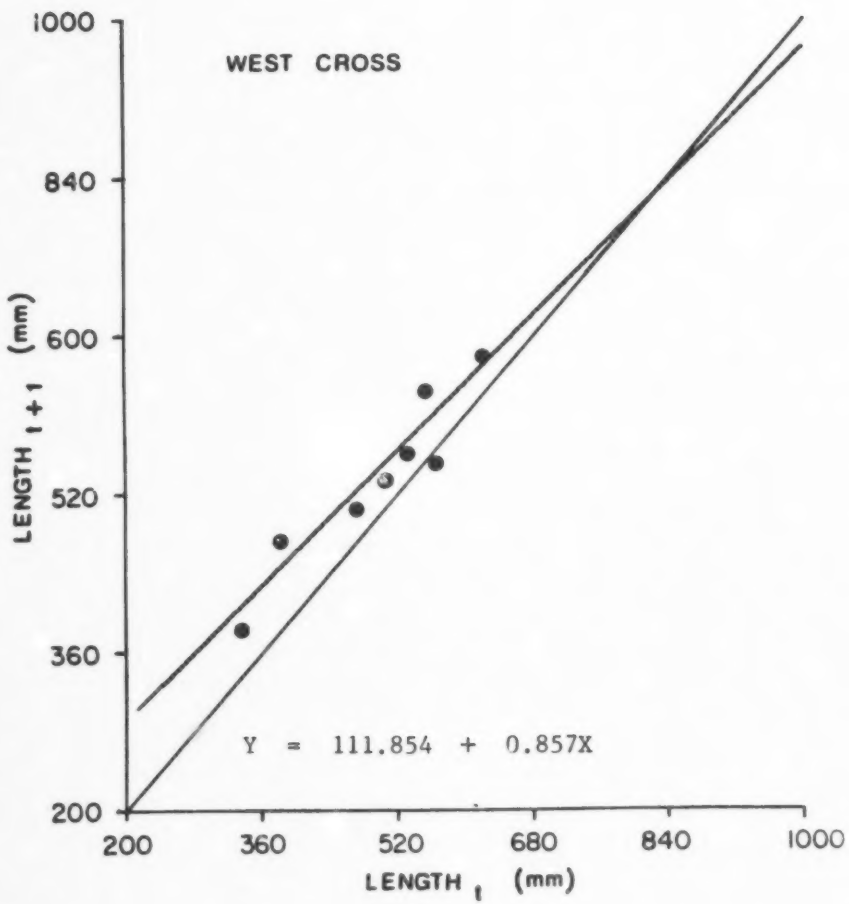
Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	4	10.26	346.00	290.00	0.70	1	1.15	325.00	240.00	0.70	5	3.97	341.80	280.00	0.70
3	3	7.69	376.67	363.33	0.68	4	4.60	369.75	365.00	0.72	7	5.56	372.71	364.29	0.70
4	9	23.08	442.56	551.11	0.63	9	10.34	442.22	551.11	0.64	18	14.29	442.39	551.11	0.63
5	12	30.77	497.17	870.83	0.70	15	17.24	512.20	869.33	0.64	27	21.43	505.52	870.00	0.67
6	7	17.95	516.86	970.00	0.70	23	26.44	563.65	1125.22	0.62	30	23.81	552.73	1089.00	0.64
7	2	5.13	559.00	1115.00	0.64	14	16.09	604.21	1497.14	0.65	16	12.70	598.56	1449.38	0.65
8	1	2.56	552.00	1080.00	0.64	5	5.75	639.20	1828.00	0.64	6	4.76	624.67	1703.33	0.64
9						7	8.05	688.29	2504.29	0.75	7	5.56	688.29	2504.29	0.75
10						4	4.60	691.75	2372.50	0.71	4	3.17	691.75	2372.50	0.71
11						1	1.15	702.00	3010.00	0.87	1	0.79	702.00	3010.00	0.87
12						2	2.30	928.00	6710.00	0.84	2	1.59	928.00	6710.00	0.84
13															
14						1	1.15	1020.00	8200.00	0.77	1	0.79	1020.00	8200.00	0.77
15															
16	1	2.56	868.00	4580.00	0.70						1	0.79	868.00	4580.00	0.70
17						1	1.15	1040.00	10560.00	0.94	1	0.79	1040.00	10560.00	0.94

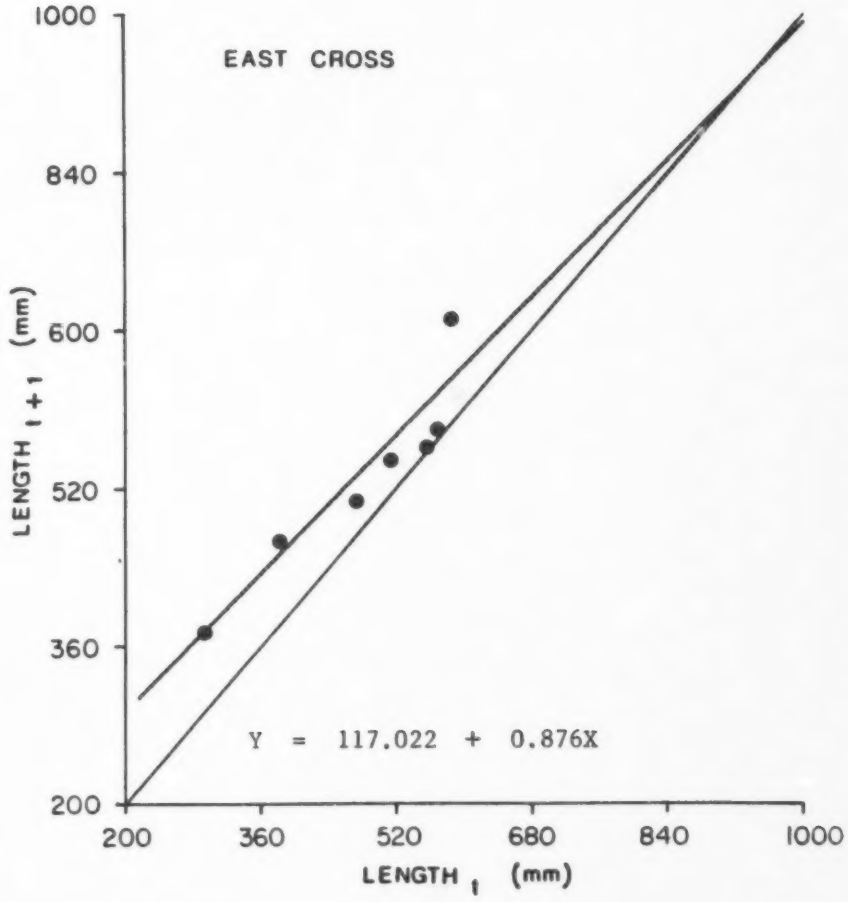
AppendixB45 . Age-specific mean lengths, weights and condition factors for pike caught in experimental sets in Walker Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2						2	1.06	326.00	255.00	0.74	2	0.78	326.00	255.00	0.74
3	2	2.86	356.00	350.00	0.78	1	0.53	372.00	400.00	0.78	3	1.16	361.33	366.67	0.78
4	5	7.14	444.00	642.00	0.74	6	3.19	463.67	690.00	0.68	11	4.26	454.73	668.18	0.71
5	7	10.00	494.86	824.29	0.68	16	8.51	515.56	921.25	0.67	23	8.91	509.26	891.74	0.67
6	11	15.71	539.55	1026.36	0.65	31	16.49	561.87	1172.90	0.65	42	16.28	556.02	1134.52	0.65
7	11	15.71	555.82	1134.55	0.66	31	16.49	606.77	1506.13	0.67	42	16.28	593.13	1408.81	0.66
8	18	25.71	598.33	1418.33	0.66	34	18.09	628.62	1585.59	0.63	52	20.16	618.13	1527.69	0.64
9	11	15.71	600.18	1357.27	0.63	27	14.36	659.07	1900.00	0.66	38	14.73	642.00	1742.89	0.65
10	4	5.71	626.00	1627.50	0.66	19	10.11	687.37	2088.95	0.64	23	8.91	676.70	2008.70	0.64
11	1	1.43	670.00	1960.00	0.65	12	6.38	725.25	2661.67	0.67	13	5.04	721.00	2607.69	0.67
12						7	3.72	712.29	2280.00	0.63	7	2.71	712.29	2280.00	0.63
13						1	0.53	758.00	3060.00	0.70	1	0.39	758.00	3060.00	0.70
14						1	0.53	750.00	2700.00	0.64	1	0.39	750.00	2700.00	0.64

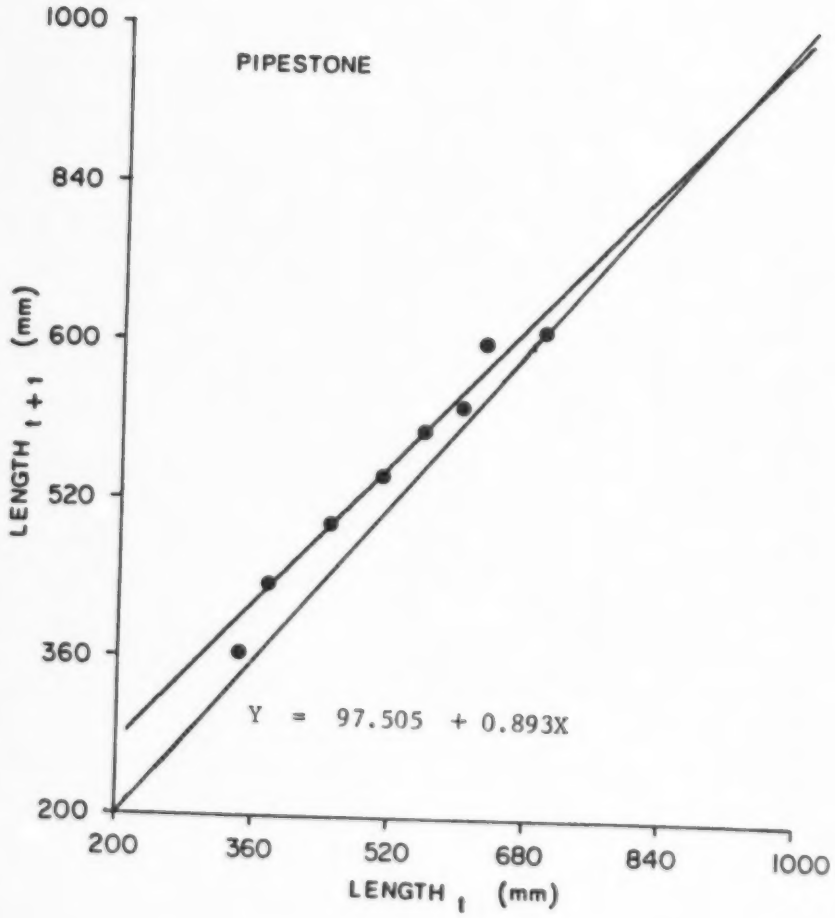
Appendix B46. Age-specific mean lengths, weights and condition factors for pike caught in commercial nets (4.25 inch mesh) in Walker Lake, 1981.

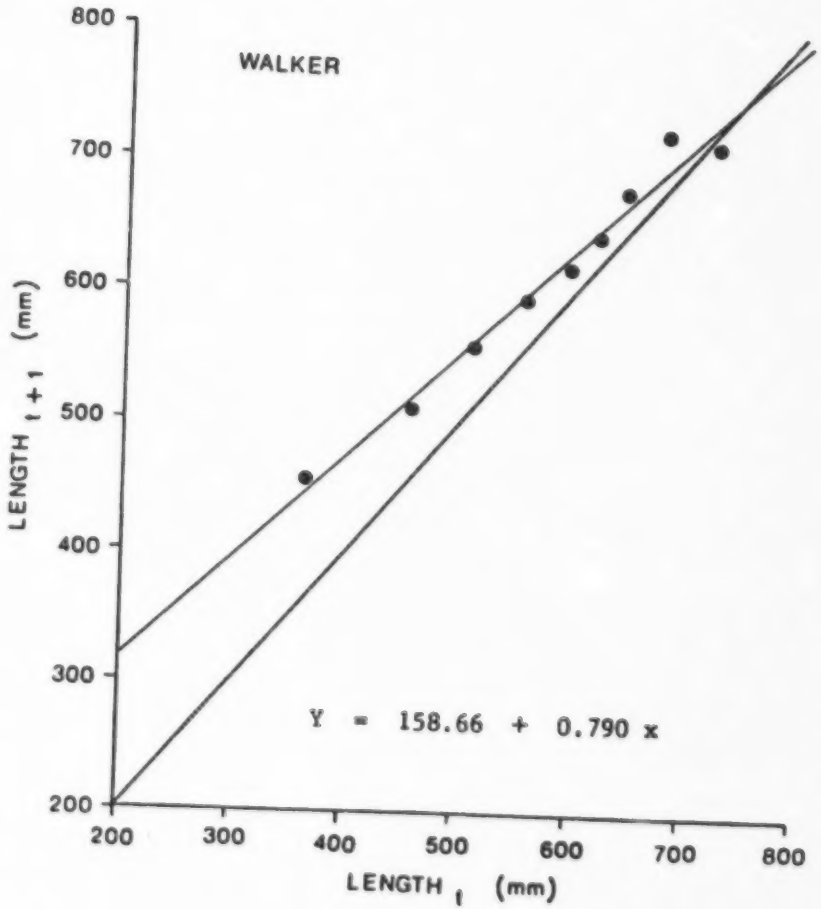
	Males					Females					Both Sexes				
Age	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
5	1	25.00	424.00	700.00	0.92						1	1.92	424.00	700.00	0.92
6															
7						1	2.08	628.00	1650.00	0.67	1	1.92	628.00	1650.00	0.67
8						7	14.58	658.86	2107.14	0.72	7	13.46	658.86	2107.14	0.72
9	2	50.00	652.00	2050.00	0.74	8	16.67	691.25	2250.00	0.67	10	19.23	683.40	2210.00	0.68
10	1	25.00	584.00	1000.00	0.50	14	29.17	709.14	2378.57	0.66	15	28.85	700.80	2286.67	0.65
11						9	18.75	761.56	3322.22	0.74	9	17.31	761.56	3322.22	0.74
12						5	10.45	758.80	3040.00	0.70	5	9.62	758.80	3040.00	0.70
13						1	2.08	824.00	4050.00	0.72	1	1.92	824.00	4050.00	0.72
14						3	6.25	816.00	4300.00	0.80	3	5.77	816.00	4300.00	0.80



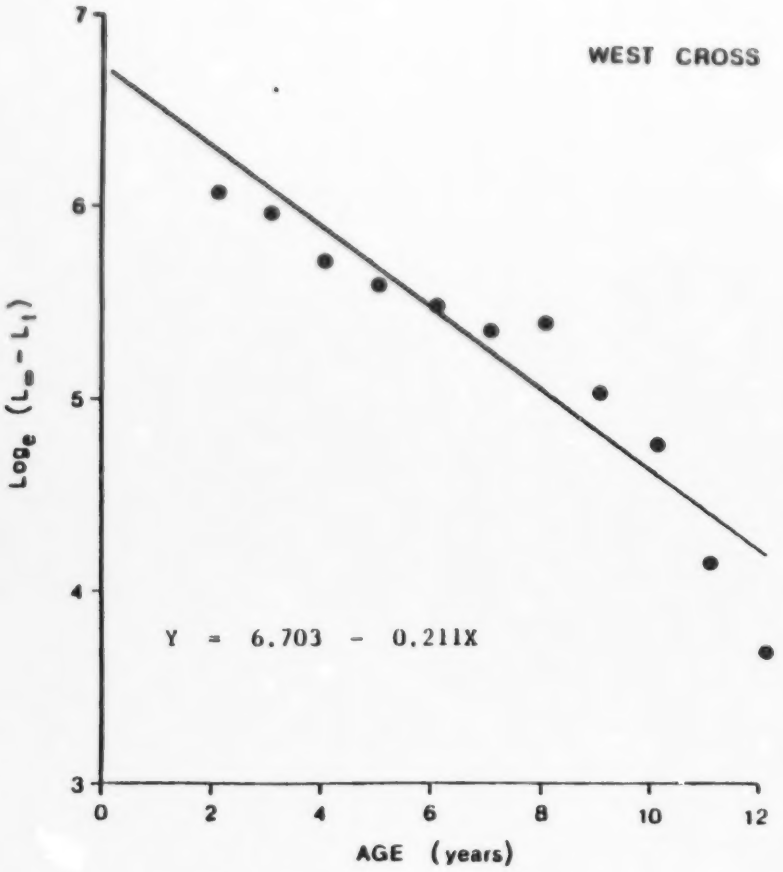


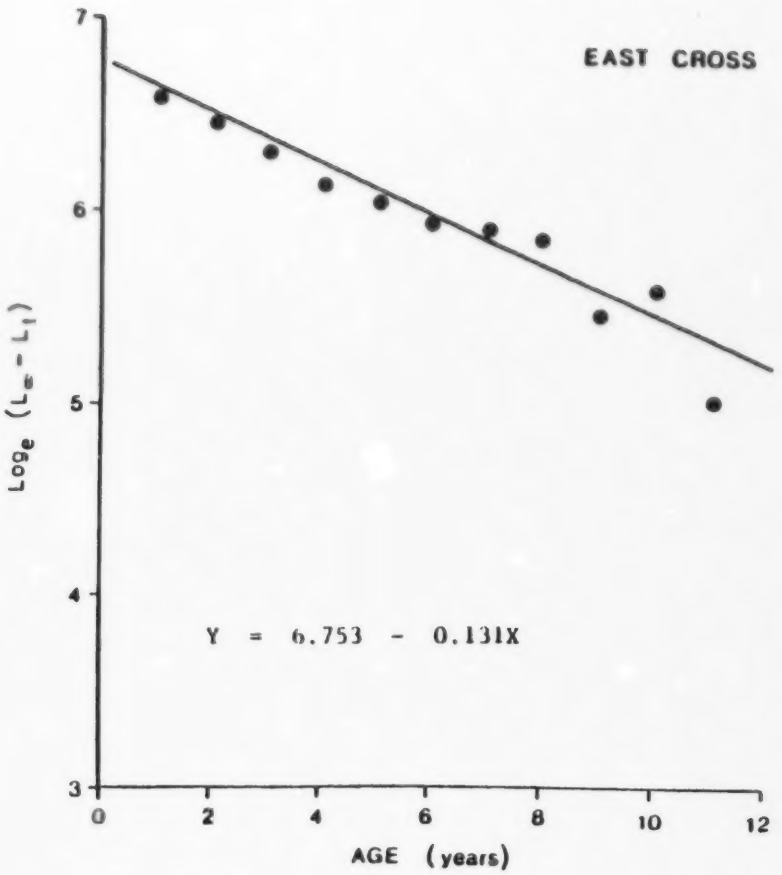
Appendix B47. Walford plots for pike from the west and east basins of Cross Lake, 1981.



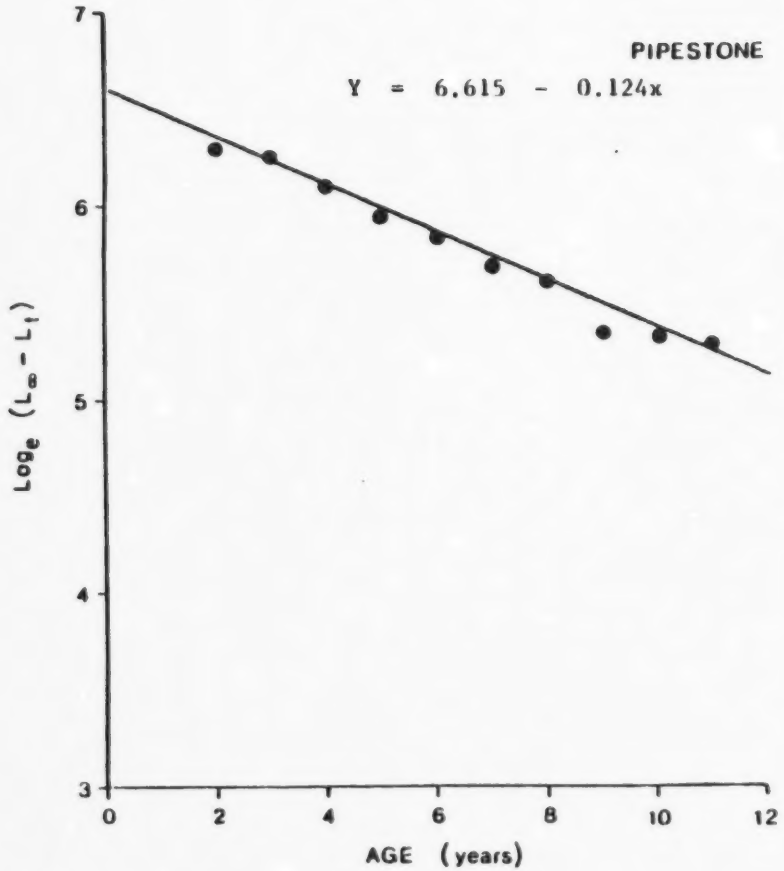


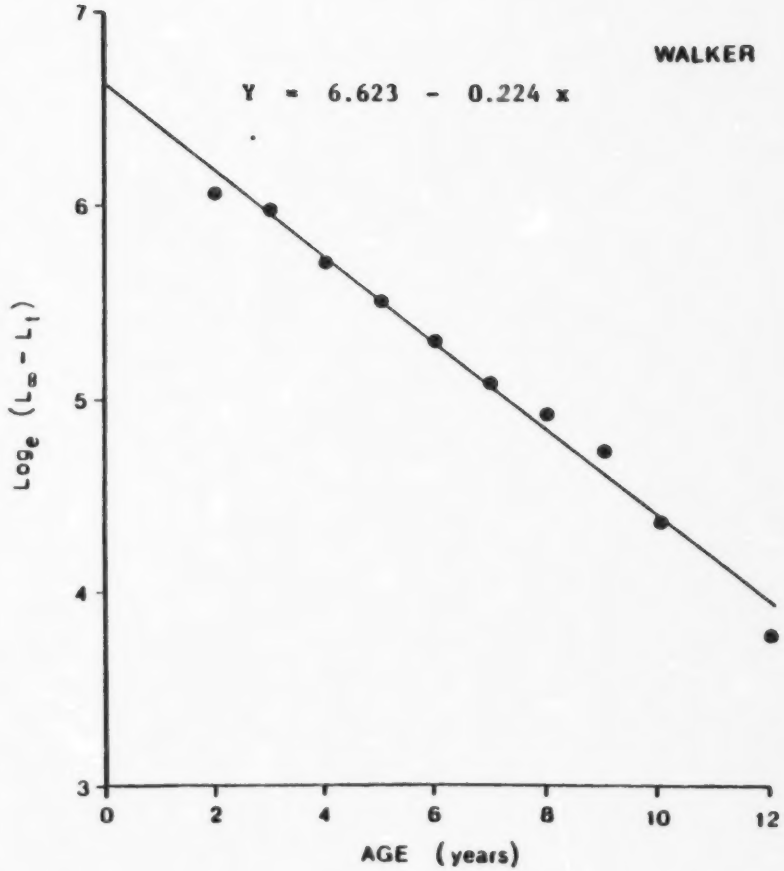
Appendix B48. Walford plots for pike from Pipestone and Walker lakes, 1981.





Appendix B49. Brody plots for pike from the west and east basins of Cross Lake, 1981.





Appendix B50. Brody plots for pike from Pipestone and Walker lakes, 1981.

Appendix B51 . Maturity schedules for pike, 1981.

Age	West Cross				East Cross				Pipestone				Walker			
	Males		Females		Males		Females		Males		Females		Males		Females	
	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.
1							3									
2			1		1					4	1				2	
3	1		7	2	2	8	5	2		3	2	2	2		1	
4	1	12	7	14		21	3	30		9		9		5	3	3
5		29	1	38	1	9		41		12		15		7	2	14
6		24		46		5		11		7		23		11		31
7	1	10		30		3		3		2		14		11		31
8		8		9		2		5		1		5		18		34
≥9		4		16		1		5		1		16		16		67

Appendix B52. Age-specific mean lengths, weights and condition factors for cisco from the Whiskey Jack basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
1	4	4.44	147.75	62.50	1.95	3	4.05	157.00	70.00	1.81	7	4.27	151.71	65.71	1.89
2	8	8.89	196.00	121.25	1.61	14	18.92	198.43	125.71	1.60	22	13.41	197.51	124.09	1.61
3	4	4.44	241.00	227.50	1.62	6	8.11	249.17	241.67	1.56	10	6.10	245.90	236.00	1.58
4	12	13.33	295.25	396.67	1.54	8	10.81	293.00	396.25	1.56	20	12.20	294.35	396.50	1.55
5	17	18.89	314.00	494.12	1.59	14	18.92	307.28	455.71	1.56	31	18.90	310.97	476.77	1.58
6	12	13.33	330.75	559.17	1.54	4	5.41	317.25	502.50	1.57	16	9.76	327.38	545.00	1.54
7	11	12.22	334.00	561.82	1.51	7	9.46	336.57	572.86	1.50	18	10.98	335.00	566.11	1.50
8	6	6.67	341.67	650.00	1.61	4	5.41	341.50	615.00	1.53	10	6.10	341.60	636.00	1.58
9	8	8.89	347.75	642.50	1.53	5	6.76	339.40	626.00	1.59	13	7.93	344.54	636.15	1.55
10	4	4.44	351.00	687.50	1.59	2	2.70	348.00	640.00	1.51	6	3.66	350.00	671.67	1.56
11	3	3.33	365.00	756.67	1.52	2	2.70	352.50	700.00	1.59	5	3.05	360.00	734.00	1.54
12						3	4.05	354.67	700.00	1.56	3	1.83	354.67	700.00	1.56
13	1	1.11	393.00	930.00	1.53	2	2.70	381.50	900.00	1.60	3	1.83	385.33	910.00	1.57

Appendix B53. Age-specific mean lengths, weights and condition factors for cisco from the middle basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	16	19.75	203.38	127.50	1.52	8	10.67	207.50	136.25	1.52	24	15.38	204.75	130.42	1.52
3	6	7.41	242.50	220.00	1.48	9	12.00	276.11	344.44	1.57	15	9.62	262.67	294.67	1.53
4	1	1.23	297.00	410.00	1.57	1	1.33	330.00	670.00	1.86	2	1.28	313.50	540.00	1.72
5	4	4.94	359.00	800.00	1.73	12	16.00	358.58	827.50	1.79	16	10.26	358.69	820.63	1.77
6	4	4.94	364.25	820.00	1.70	7	9.33	379.86	985.71	1.78	11	7.05	374.18	925.45	1.75
7	5	6.17	382.60	1024.00	1.83	6	8.00	372.00	861.67	1.66	11	7.05	376.82	935.45	1.73
8	11	13.58	374.27	940.91	1.79	8	10.67	391.63	1095.00	1.82	19	12.18	381.58	1005.79	1.80
9	8	9.88	391.88	1115.00	1.85	12	16.00	372.67	904.17	1.74	20	12.82	380.35	988.50	1.78
10	9	11.11	383.22	1014.44	1.80	3	4.00	387.33	973.33	1.67	12	7.69	384.25	1004.17	1.77
11	9	11.11	389.33	1048.89	1.76	5	6.67	389.00	1078.00	1.84	14	8.97	389.21	1059.29	1.78
12	5	6.17	387.20	1010.00	1.72	2	2.67	416.00	1240.00	1.72	7	4.49	395.43	1075.71	1.72
13	2	2.47	370.50	860.00	1.69	1	1.33	402.00	1130.00	1.74	3	1.92	381.00	950.00	1.71
14						1	1.33	416.00	1370.00	1.90	1	0.64	416.00	1370.00	1.90
15	1	1.23	416.00	1150.00	1.60						1	0.64	416.00	1150.00	1.60

Appendix B54. Age-specific mean lengths, weights and condition factors for cisco from the east basin of Cross Lake, 1981.

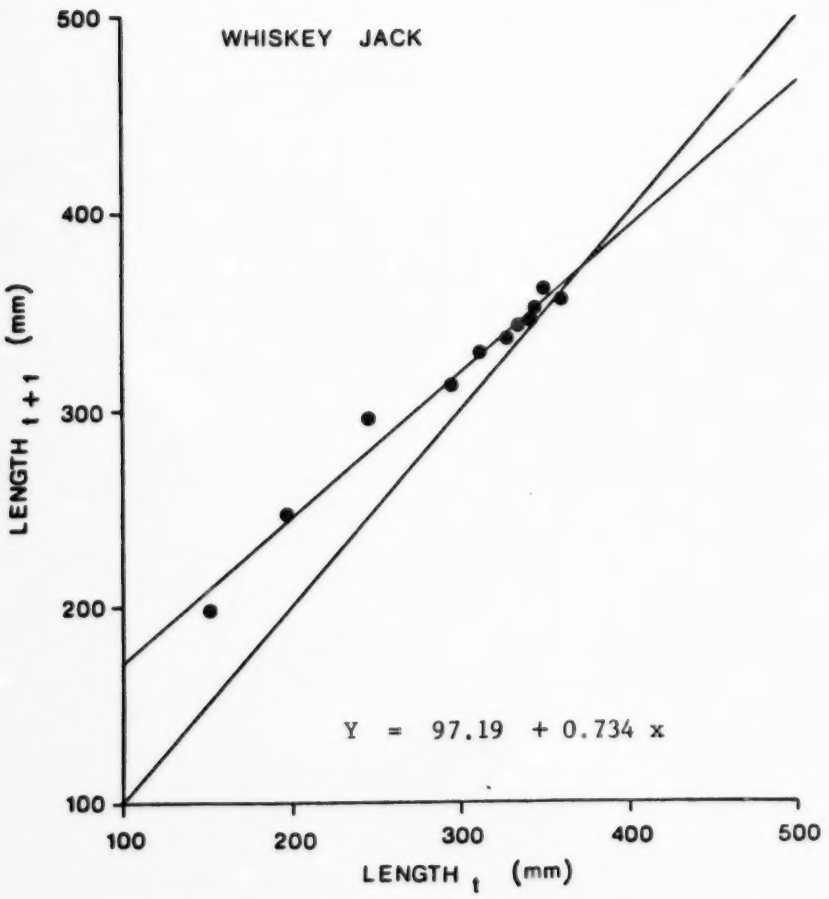
Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
1						1	0.63	159.00	80.00	1.99	1	0.34	159.00	80.00	1.99
2	46	33.09	230.67	216.41	1.75	49	31.01	235.02	222.24	1.70	95	31.99	232.92	219.42	1.72
3	14	10.07	310.79	585.71	1.90	12	7.59	299.33	503.33	1.82	26	8.75	305.50	547.69	1.86
4	6	4.32	367.17	963.33	1.93	5	3.16	358.60	914.00	1.97	11	3.70	363.27	940.91	1.95
5	6	4.32	370.83	968.33	1.89	10	6.33	380.70	1105.00	1.98	16	5.39	377.00	1053.75	1.95
6	9	6.47	372.56	985.56	1.89	7	4.43	385.71	1148.57	2.00	16	5.39	378.31	1056.88	1.94
7	11	7.91	382.82	1038.18	1.84	16	10.13	392.44	1193.13	1.97	27	9.09	388.52	1130.00	1.92
8	20	14.39	386.00	1099.50	1.90	32	20.25	394.97	1230.00	1.98	52	17.51	391.52	1179.81	1.95
9	10	7.19	391.10	1116.00	1.86	8	5.06	402.50	1261.25	1.94	18	6.06	396.17	1180.56	1.89
10	8	5.76	392.50	1202.50	1.98	8	5.06	407.50	1313.75	1.93	16	5.39	400.00	1258.13	1.96
11	4	2.88	408.00	1282.50	1.88	6	3.80	405.17	1271.67	1.91	10	3.37	406.30	1276.00	1.90
12	1	0.72	382.00	940.00	1.69	2	1.27	400.50	1275.00	1.95	3	1.01	394.33	1163.33	1.86
13	2	1.44	383.00	1070.00	1.92						2	0.67	383.00	1070.00	1.92
14															
15	1	0.72	416.00	1170.00	1.63						1	0.34	416.00	1170.00	1.63

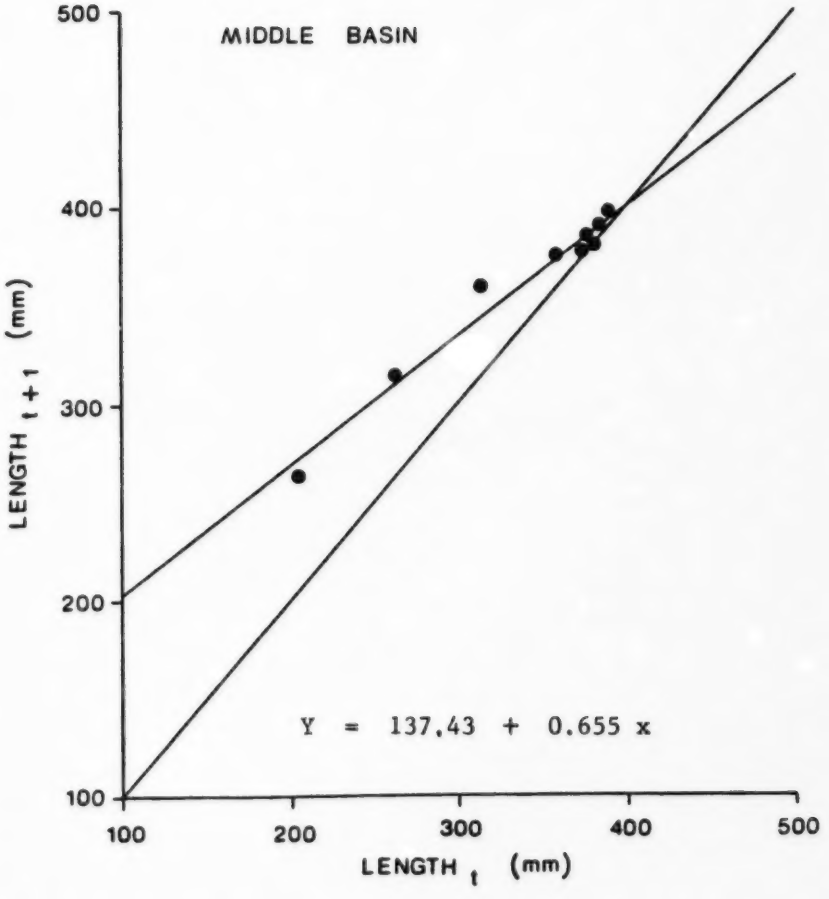
Appendix B55. Age-specific mean lengths, weights and condition factors for cisco from Pipestone Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
3	1	2.22	295.00	390.00	1.52						1	1.37	295.00	390.00	1.52
4	1	2.22	345.00	730.00	1.78						1	1.37	345.00	730.00	1.78
5	2	4.44	340.50	685.00	1.69	1	3.57	316.00	480.00	1.52	3	4.11	332.33	616.67	1.63
6	5	11.11	342.80	690.00	1.68	14	50.00	334.86	631.43	1.64	19	26.03	336.95	646.84	1.65
7	4	8.89	363.50	762.50	1.58	2	7.14	340.00	615.00	1.52	6	8.22	355.67	713.33	1.56
8	10	22.22	349.80	726.00	1.68	5	17.86	372.20	868.00	1.67	15	20.55	357.27	773.33	1.68
9	9	20.00	352.78	738.89	1.62	4	14.29	369.25	862.50	1.61	13	17.81	357.85	776.92	1.62
10	5	11.11	360. 80	776.00	1.59	1	3.57	408.00	1200.00	1.77	6	8.22	368.67	846.67	1.62
11	4	8.89	372.75	837.50	1.60						4	5.48	372.75	837.50	1.60
12						1	3.57	366.00	630.00	1.28	1	1.37	366.00	630.00	1.28
13	2	4.44	406.00	1000.00	1.50						2	2.74	406.00	1000.00	1.50
14	1	2.22	380.00	640.00	1.17						1	1.37	380.00	640.00	1.17
15	1	2.22	374.00	910.00	1.74						1	1.37	374.00	910.00	1.74

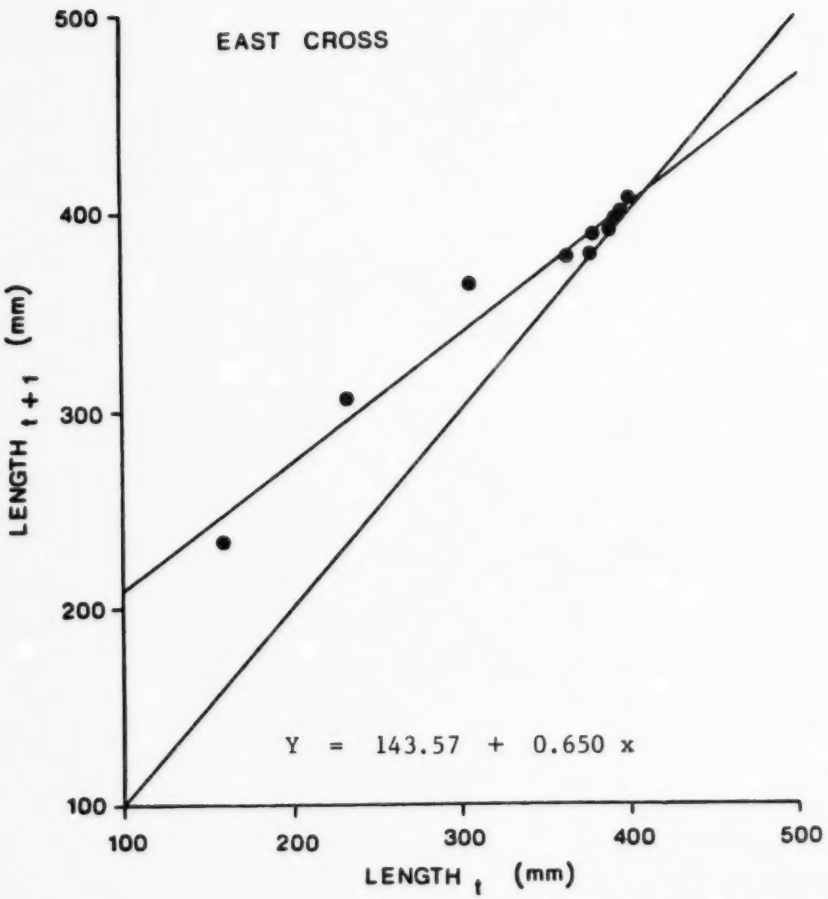
Appendix B56. Age-specific mean lengths, weights and condition factors for cisco from Walker Lake, 1981.

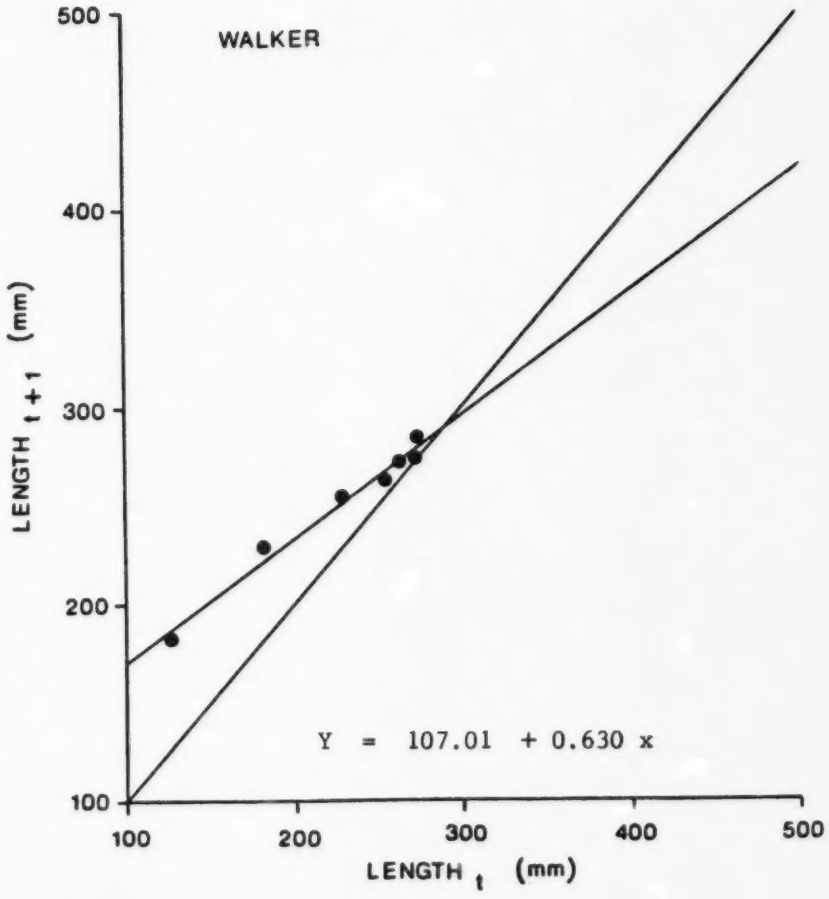
Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
1	2	1.65	126.50	37.50	1.79	1	0.68	130.00	60.00	2.73	4	1.44	126.75	43.75	2.10
2	31	25.62	182.61	99.68	1.63	40	27.03	182.83	97.75	1.60	79	28.42	182.47	98.23	1.61
3	30	24.79	228.33	180.00	1.50	21	14.19	229.24	181.90	1.50	51	18.35	228.71	180.78	1.50
4	14	11.57	250.93	240.00	1.51	24	16.22	256.33	254.17	1.50	38	13.67	254.34	248.95	1.51
5	32	26.45	264.53	280.63	1.51	35	23.65	261.57	265.71	1.48	67	24.10	262.99	272.84	1.50
6	3	2.48	270.33	310.00	1.54	14	9.46	272.14	315.00	1.54	17	6.12	271.82	314.12	1.54
7	5	4.13	271.20	302.00	1.50	5	3.38	276.20	302.00	1.43	10	3.60	273.70	302.00	1.47
8	1	0.83	288.00	390.00	1.63	3	2.03	282.67	303.33	1.34	4	1.44	284.00	325.00	1.41
9	1	0.83	270.00	300.00	1.52	3	2.03	298.67	436.67	1.59	4	1.44	291.50	402.50	1.58
10															
11															
12	1	0.83	364.00	860.00	1.78						1	0.36	364.00	860.00	1.78



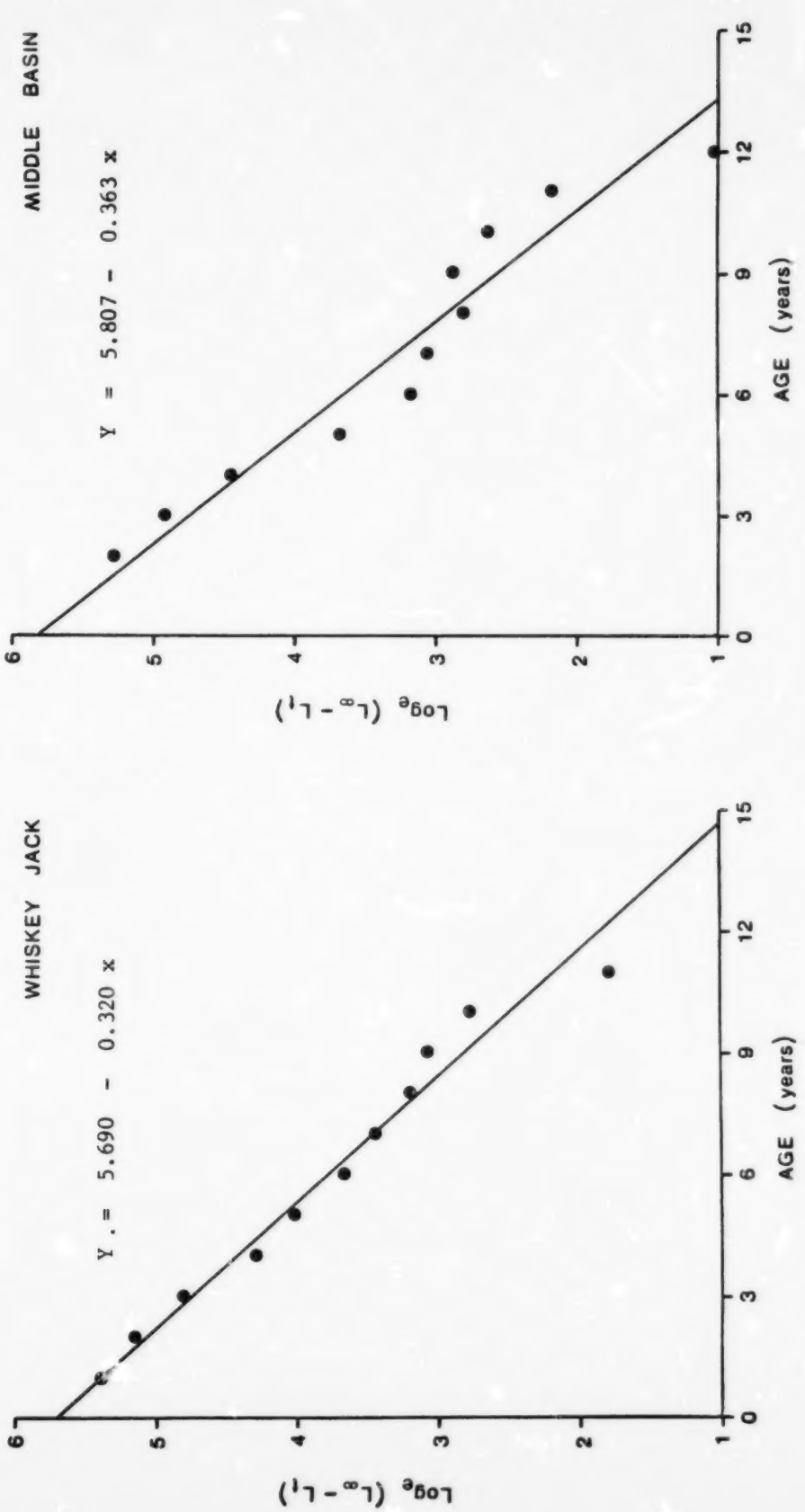


Appendix B57. Walford plots for cisco from the Whiskey Jack and middle basins of Cross Lake, 1981.

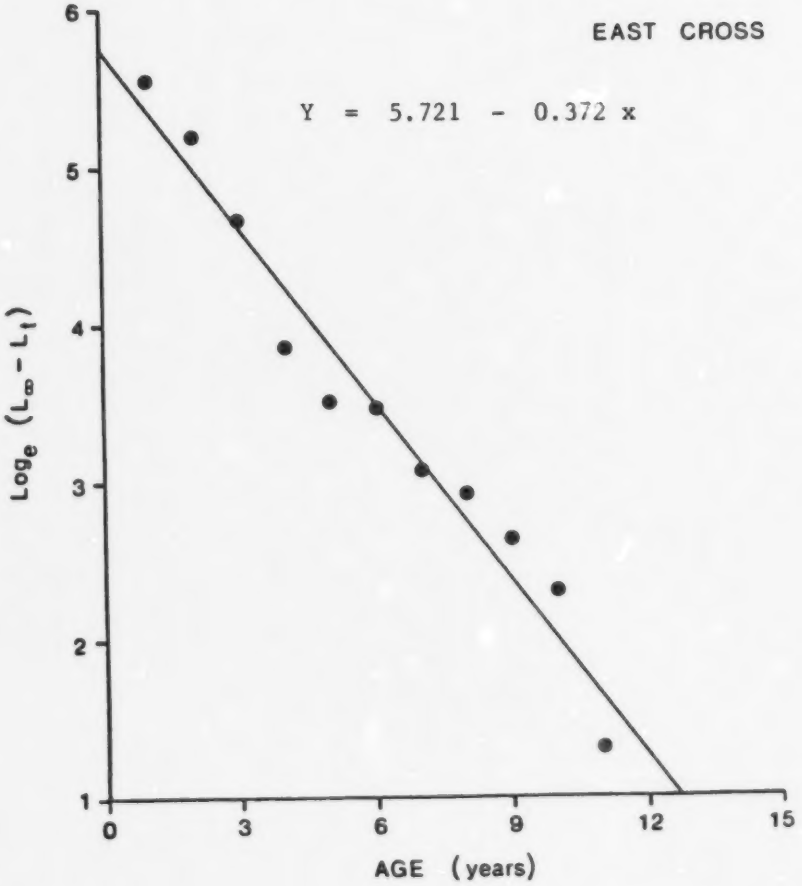


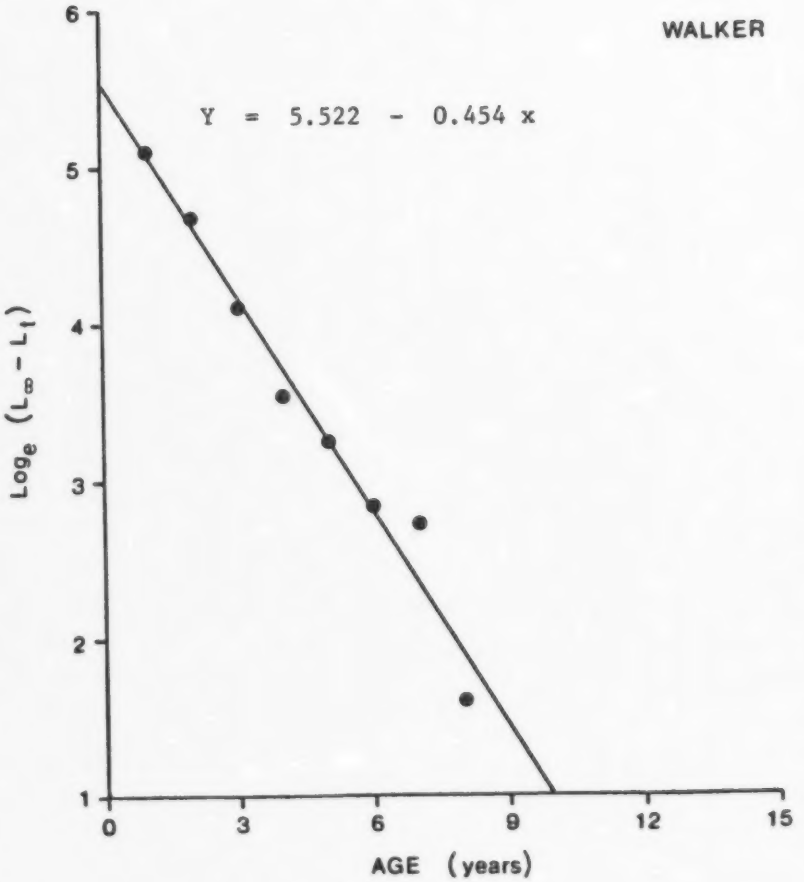


Appendix B58. Walford plots for cisco from east Cross and Walker lakes, 1981.



Appendix B59. Brody plots for cisco from the Whiskey Jack and middle basins of Cross Lake, 1981.





Appendix B60. Brody plots for cisco from east Cross and Walker lakes, 1981.

Appendix B61. Maturity schedules for cisco, 1981.

	Whiskey Jack				Middle Basin				East Cross				Pipestone				Walker			
	Males		Females		Males		Females		Males		Females		Males		Females		Males		Females	
Age	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.	Imm.	Mat.
1	4		3								1						2		1	
2	8		14		16		8		44	2	49						28	3	38	2
3	4		6		6		9		3	11	7	5	1				5	25	6	15
4	1	11	3	5		1	1			6		5		1				14		24
5		17	1	13		4		12		6		10	1	1		1	1	31	1	34
6		12		4		4		7		9		7		5	6	8		3		14
7		11		7		5		6		11		16		4	1	1		5		5
8		6		4		11		8		20		32		10		5		1		3
≥9		16		14		34		24		26		24		22	1	5	1	1		3

Appendix B62. Age-specific mean lengths, weights and condition factors for sauger from the west basin of Cross Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2						1	3.85	184.00	60.00	0.96	1	1.89	184.00	60.00	0.96
3															
4															
5	2	7.41	290.00	235.00	0.96	4	15.38	270.25	187.50	0.92	6	11.32	276.83	203.33	0.93
6						1	3.85	318.00	290.00	0.90	1	1.89	318.00	290.00	0.90
7	1	3.70	296.00	260.00	1.00	6	23.08	322.17	336.67	0.99	7	13.21	318.43	325.71	0.99
8	1	3.70	316.00	320.00	1.01						1	1.89	316.00	320.00	1.01
9	3	11.11	323.33	323.33	0.95	3	11.54	349.00	390.00	0.91	6	11.32	336.17	356.67	0.93
10	4	14.81	330.50	357.50	0.99	1	3.85	352.00	450.00	1.03	5	9.43	334.80	376.00	1.00
11	14	51.85	327.71	366.43	1.04	8	30.77	347.75	416.25	0.98	22	41.51	335.00	384.55	1.02
12															
13															
14															
15						1	3.85	391.00	560.00	0.94	1	1.89	391.00	560.00	0.94
16						1	3.85	375.00	490.00	0.93	1	1.89	375.00	490.00	0.93
17															
18	2	7.41	387.00	575.00	0.99						2	3.77	387.00	575.00	0.99

Appendix B63. Age-specific mean lengths, weights and condition factors for sauger from Pipestone Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
2	1	14.29	222.00	100.00	0.91										
3											1	8.33	222.00	100.00	0.91
4															
5	1	14.29	264.00	180.00	0.98										
6											1	8.33	264.00	180.00	0.98
7	3	42.86	327.33	376.67	1.08	2	40.00	324.00	360.00	1.06	2	16.67	324.00	360.00	1.06
8											3	25.00	327.33	376.67	1.08
9	1	14.29	333.00	370.00	1.00	2	40.00	363.00	435.00	0.91					
10											3	25.00	353.00	413.33	0.94
11															
12						1	20.00	402.00	670.00	1.03	1	8.33	402.00	670.00	1.03
13	1	14.29	336.00	360.00	0.95										
											1	8.33	336.00	360.00	0.95

Appendix B64. Age-specific mean lengths, weights and condition factors for sauger from Walker Lake, 1981.

Age	Males					Females					Both Sexes				
	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor	Number caught	Frequency (%)	Mean length (mm)	Mean weight (g)	Mean cond. factor
4	2	20.00	229.00	145.00	1.17	1	7.14	208.00	100.00	1.11	3	12.50	222.00	130.00	1.15
5	4	40.00	271.50	192.50	0.96	3	21.43	263.33	176.67	0.96	7	29.17	268.00	185.71	0.96
6	1	10.00	282.00	200.00	0.89	1	7.14	266.00	200.00	1.06	2	8.33	274.00	200.00	0.98
7	1	10.00	332.00	380.00	1.04	1	7.14	367.00	480.00	0.97	2	8.33	349.50	430.00	1.01
8						5	35.71	340.20	362.00	0.92	5	20.83	340.20	362.00	0.92
9						1	7.14	330.00	300.00	0.83	1	4.17	330.00	300.00	0.83
10	1	10.00	344.00	400.00	0.98	1	7.14	362.00	440.00	0.93	2	8.33	353.00	420.00	0.96
11															
12															
13						1	7.14	432.00	800.00	0.99	1	4.17	432.00	800.00	0.99
14															
15															
16	1	10.00	420.00	740.00	1.00						1	4.17	420.00	740.00	1.00

Appendix B65. Water level drawdown between fall and spring in Cross Lake, 1918 - 1973. Data provided by Manitoba Water Resources Branch.

Year	Water Level on October 28 (m)	Minimum Water Level between October 28 and May 31 (m)	Water Level Drawdown between October 28 and May 31 (m)
1918-19	207.11	206.01(Apr. 27)	1.10
1920-21	207.00	205.84(Feb. 26)	1.16
1921-22	207.03	206.06(Mar. 29)	0.98
1922-23	207.08	206.04(Apr. 18)	1.04
1923-24	207.14	205.77(Apr. 26)	1.37
1924-25	206.98	205.95(Mar. 31)	1.03
1925-26	207.06	206.33(Apr. 26)	0.73
1926-27	206.79	206.48(Mar. 28)	0.31
1927-28	208.08	206.94(Apr. 17)	1.14
1928-29	207.46	206.39(Apr. 14)	1.07
1929-30	206.56	205.99(Jan. 16)	0.57
1930-31	206.05	205.58(Mar. 30)	0.47
1932-33	206.10	205.51(Mar. 26)	0.59
1950-51	208.11	207.00(Apr. 14)	1.11
1951-52	207.58	206.70(Apr. 5)	0.88
1952-53	207.30	206.62(Mar. 5)	0.68
1953-54	207.61	206.48(Apr. 13)	1.13
1954-55	208.16	207.28(Apr. 6)	0.88
1955-56	207.74	206.94(Apr. 13)	0.80
1956-57	207.63	206.51(Apr. 19)	1.12
1958-59	206.71	206.09(Apr. 12)	0.62
1959-60	207.29	206.65(Apr. 16)	0.64
1960-61	206.97	206.15(Apr. 18)	0.81
1961-62	206.19	205.50(Apr. 15)	0.69
1962-63	206.93	206.22(Apr. 10)	0.71
1963-64	207.05	206.11(Apr. 8)	0.94
1964-65	206.82	206.36(Apr. 8)	0.46
1965-66	207.72	207.25(Mar. 28)	0.48
1966-67	207.94	207.25(Apr. 13)	0.69
1967-68	207.29	206.63(Apr. 8)	0.66
1968-69	207.46	207.17(Dec. 11)	0.29
1969-70	207.95	207.49(Apr. 18)	0.46
1970-71	207.79	207.40(Apr. 7)	0.39
1971-72	207.51	207.30(Apr. 10)	0.21
1972-73	207.22	206.91(Mar. 24)	0.31
Mean	207.24	206.48	0.76

Appendix C1 . Number of domestic fishermen using 4.25 and/or 5.25 inch nets between August 4, 1980 and August 2 , 1981.

Period	Number of fishermen		
	4.25 inch	5.25 inch	Total
Aug. 4-17	5	12	13
Aug. 18-31	9	11	17
Sept. 1-14	7	14	18
Sept. 15-28	7	14	17
Sept. 29-Oct. 12	6	9	13
Oct. 13-26	5	17	17
Oct. 27-Nov. 9	2	11	12
Nov. 10-23	2	11	12
Nov. 24-Dec. 7	3	10	11
Dec. 8-21	2	8	10
Dec. 22-Jan. 4	4	7	10
Jan. 5-18	7	7	13
Jan. 19-Feb. 1	7	6	12
Feb. 2-15	6	8	11
Feb. 16-Mar. 1	6	8	11
Mar. 2-15	5	4	7
Mar. 16-29	4	2	5
Mar. 30-Apr. 12	5	3	7
Apr. 13-26	3	4	5
Apr. 27-May 10	4	4	7
May 11-24	3	6	9
May 25-June 7	5	7	9
June 8-21	2	7	9
June 22-July 5	4	8	11
July 6-19	6	7	12
July 20-Aug. 2	5	5	8

Appendix C2 . Total catches in 4.25 inch mesh by each domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 2, 1981.

Fishermen	Total length of net (yds)	Number of fish caught				
		Whitefish	Walleye	Pike	Cisco	Suckers
3	2450	142	506	80	548	357
5	660	18	111	8	209	67
6	2810	23	304	94	349	314
10	400	7	113	12	23	20
11	6525	77	1328	205	645	746
13	5000	681	781	222	679	377
14	300	55	17	1	18	36
15	2250	125	161	75	393	264
16	6800	231	1944	316	3115	2264
17	830	50	74	132	213	43
18	900	65	155	37	109	134
19	1050	14	122	33	29	165
20	3220	424	1157	203	1068	929
21	8200	375	633	234	585	519
22	1670	143	502	254	498	605
Total	43065	2430	7908	1906	8481	6840

Appendix C3 . Total catches in 5.25 inch mesh by each domestic fishermen in Cross Lake between Aug. 4, 1980 and Aug. 2, 1981.

Fishermen	Total length of net (yds)	Number of fish caught				
		Whitefish	Walleye	Pike	Cisco	Suckers
1	8050	989	898	557	2535	3533
2	250	10	2	2	5	5
3	3000	355	78	18	711	131
4	5400	969	427	314	808	331
5	12100	956	292	190	511	1108
6	3600	422	73	108	81	116
7	4900	552	116	73	193	88
8	250	14	18	8	15	14
9	5100	670	177	82	671	184
11	10400	771	160	177	1096	451
12	1900	211	48	44	306	128
13	22700	1373	2041	410	2358	959
14	1200	122	112	47	128	120
15	7100	562	502	381	750	455
16	2100	186	280	89	389	476
17	1600	63	66	62	306	130
18	1500	237	252	164	275	271
19	4200	314	88	157	290	407
20	5660	1003	1787	357	1826	1322
21	11350	800	729	306	901	1000
22	410	60	148	75	181	117
Total	112770	10639	8294	3621	14336	11346

Appendix C4 . Number of fish caught in 4.25 inch mesh by the domestic fishermen in Cross Lake for each biweekly period between Aug. 4, 1980 and Aug. 30, 1981.

Period	Total length of net (yds)	Whitefish	Walleye	Pike	Cisco	Suckers
Aug. 4-17	1520	77	272	32	182	321
Aug. 18-31	1995	41	533	45	180	416
Sept. 1-14	2225	79	562	41	318	485
Sept. 15-28	2275	168	495	89	678	290
Sept. 29-Oct.12	940	87	221	39	316	113
Oct.13-26	960	144	128	33	429	91
Oct.27-Nov. 9	200	7	2	12	53	0
Nov. 10-23	850	85	127	107	213	132
Nov. 24-Dec. 7	260	11	86	35	67	49
Dec.8-21	280	6	34	9	18	25
Dec. 22-Jan. 4	1040	35	139	68	101	86
Jan. 5-18	4330	221	612	140	488	521
Jan. 19-Feb. 1	3675	107	465	147	446	417
Feb. 2-15	2205	65	267	81	204	183
Feb. 16-Mar. 1	2165	57	511	120	241	207
Mar. 2-15	1910	91	421	102	1063	451
Mar. 16-29	2085	134	1046	151	1313	973
Mar. 30-Apr. 12	2240	115	575	127	871	821
Apr. 13-26	1420	43	119	31	159	78
Apr. 27-May 10	950	58	91	38	80	90
May 11-24	1170	47	82	84	67	118
May 25-June 7	1795	142	204	82	223	307
June 8-21	1000	82	132	76	56	45
June 22-July 5	1170	50	116	61	88	189
July 6-19	2380	239	280	95	339	276
July 20-Aug 2	2025	239	388	61	288	156
Aug. 4, 1980-Aug. 2, 1981	43065	2430	7908	1906	8481	6840
Aug. 3-16,1981-	3120	132	241	51	279	249
Aug.17-30,1981	2395	149	120	33	93	123

Appendix C5 . Number of fish caught in 5.25 inch mesh by the domestic fishermen in Cross Lake for each biweekly period between Aug. 4, 1980 and Aug. 30, 1981.

Period	Total length of net (yds)	Whitefish	Walleye	Pike	Cisco	Suckers
Aug. 4-17	4010	392	269	82	461	275
Aug. 18-31	5550	926	389	158	677	308
Sept. 1-14	5975	419	381	184	459	410
Sept. 15-28	5100	421	290	127	512	386
Sept. 29-Oct. 12	4970	534	331	108	590	345
Oct. 13-26	9580	1424	475	181	2371	518
Oct. 27-Nov. 9	4085	567	176	74	905	228
Nov. 10-23	6280	420	398	197	437	514
Nov. 24-Dec. 7	5395	436	353	236	503	723
Dec. 8-21	4245	434	382	206	647	689
Dec. 22-Jan. 4	3180	295	266	122	376	500
Jan. 5-18	4870	259	380	120	563	464
Jan. 19-Feb. 1	4340	251	339	129	304	385
Feb. 2-15	6635	526	634	201	707	633
Feb. 16-Mar. 1	6870	641	737	238	890	846
Mar. 2-15	1560	118	237	82	619	374
Mar. 16-29	820	137	209	68	314	455
Mar. 30-Apr. 12	1690	47	270	48	285	186
Apr. 13-26	2265	91	350	89	414	340
Apr. 27-May 10	2700	197	189	70	356	321
May 11-24	4300	396	363	210	557	751
May 25-June 7	4495	541	223	175	322	499
June 8-21	4155	481	234	197	297	488
June 22-July 5	4250	266	221	164	355	490
July 6-19	4400	348	179	136	363	198
July 20-Aug. 2	1050	72	19	19	52	20
Aug. 4, 1980-Aug. 2, 1981	112770	10639	8294	3621	14336	11346
Aug. 3-16, 1981	3000	257	74	56	174	181
Aug. 17-30, 1981	3100	245	128	24	141	78